DOCUMENT RESUME

ED 287 712 SE 048 671

TITLE	Operation and Maintenance of Wastewater Collection Systems. Volume I. Third Edition. A Field Study Training Program.
INSTITUTION	California State Univ., Sacramento. Dept. of Civil Engineering.; California Water Pollution Control Association, Sacramento.
SPONS AGENCY	Environmental Protection Agency, Washington, D.C. Office of Water Programs.
PUB DATE	87
GRANT	T900494
NOTE	561p.; For Volume II, see SE 048 672. For related publications, see ED 196 689 and ED 286 742-743. Photographs may not reproduce well; pages containing final examinations and answers are printed on dark grey paper and may be illegible.
AVAILABLE FROM	Office of Water Programs, California State University, Sacramento, 6000 J Street, Sacramento, CA 95819-2654 ($7.00).
PUB TYPE	Guides - Classroom Use - Materials (For Learner) (051) -- Guides - Classroom Use - Guides (For Teachers) (052) -- Tests/Evaluation Instruments (160)
EDRS PRICE	MF02 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS	College Science; Distance Education; Environmental Education; Environmental Standards; Glossaries; Higher Education; *Home Study; *Job Skills; *Postsecondary Education; Science Activities; Science and Society; Science Curriculum; Science Education; Science Instruction; *Vocational Education; Waste Disposal; *Waste Water; *Water Treatment
IDENTIFIERS	*Waste Water Treatment Plant Personnel

ABSTRACT

Proper installations, inspections, operations, maintenance and repairs of wastewater collection, conveyance and treatment facilities have a significant impact on the operation and maintenance costs, and the effectiveness of these facilities. This manual is the first volume of a two-part program designed to provide wastewater collection system operators with the knowledge and skills to effectively operate and maintain collection systems. Originally developed as a part of a home-study course for collection system operators in remote areas, it is now used as a text in college and university classes. This volume contains chapters dealing with: (1) the wastewater system operator; (2) why collection systems operations are done; (3) different types of wastewater collection systems; (4) safe procedures; (5) inspecting and testing collection systems; (6) pipeline cleaning and maintenance methods; and (7) underground repair. Included is a final examination, a glossary, applications of arithmetic problems to collection systems, and an index. (TW)

****
*   Reproductions supplied by EDRS are the best that can be made   *
*   from the original document.   *
****

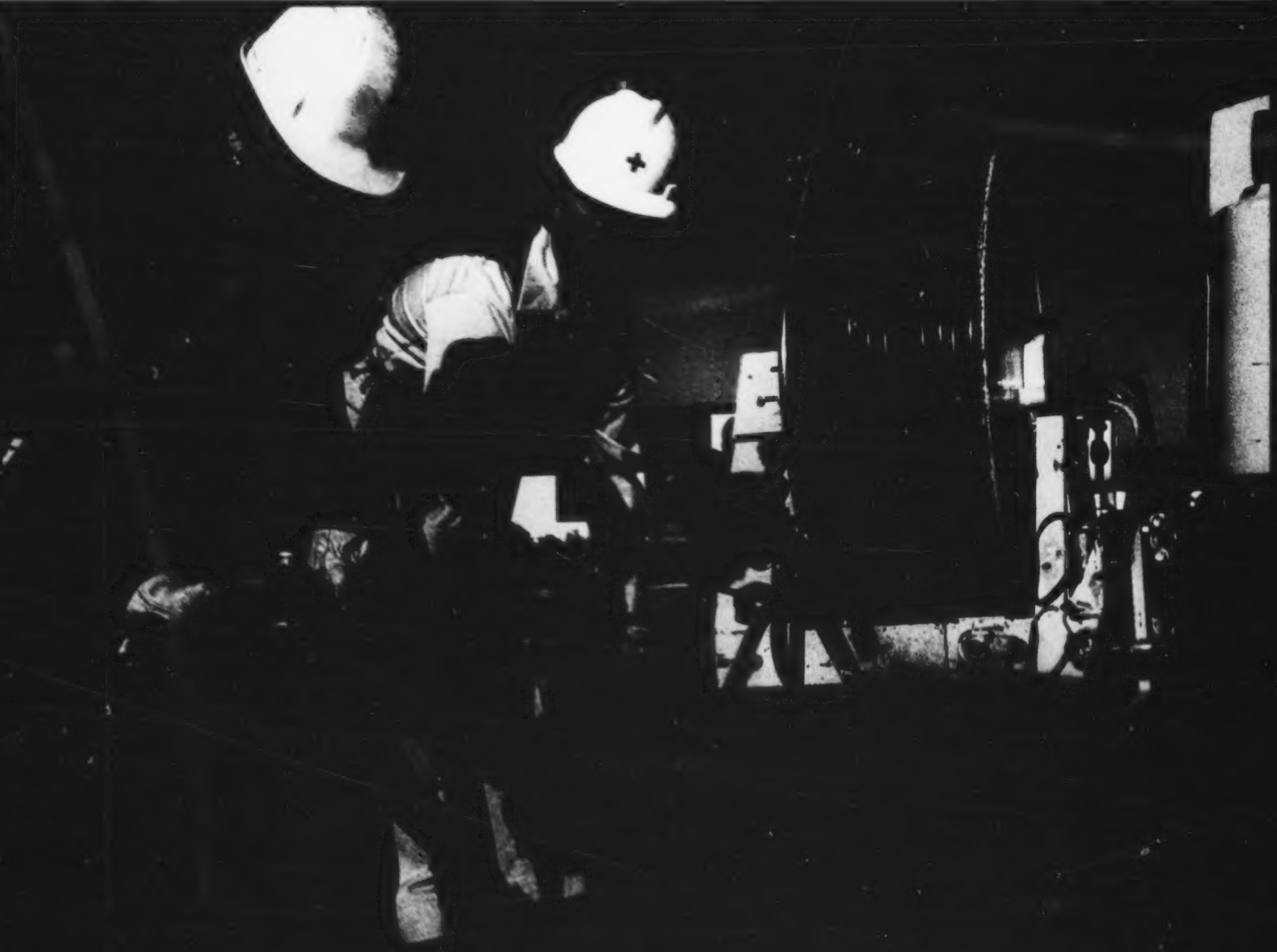
BEST COPY AVAILABLE

OPERATION AND MAINTENANCE OF WASTEWATER COLLECTION SYSTEMS

A FIELD STUDY TRAINING PROGRAM

VOLUME 1

ED287712



"PERMISSION TO REPRODUCE THIS MATERIAL IN MICROFICHE ONLY HAS BEEN GRANTED BY

Ken Kerri

TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)."

U.S. DEPARTMENT OF EDUCATION
Office of Educational Research and Improvement
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)

☒ This document has been reproduced as received from the person or organization originating it.
☐ Minor changes have been made to improve reproduction quality

- Points of view or opinions stated in this document do not necessarily represent official OERI position or policy

SE 049 671

- U.S. Environmental Protection Agency
- Office of Water Programs

ENVIRONMENTAL PROTECTION AGENCY REVIEW NOTICE

This training manual has been reviewed by the Office of Water Program Operations, U.S. Environmental Protection Agency, and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Environmental Protection Agency. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the Environmental Protection Agency, California State University, Sacramento, California Water Pollution Control Association, authors of the chapters or project reviewers and directors.

OPERATION AND MAINTENANCE OF WASTEWATER COLLECTION SYSTEMS

Third Edition
Volume I

A Field Study Training Program

prepared by

California State University, Sacramento
Department of Civil Engineering
Office of Water Programs

in cooperation with
California Water Pollution Control Association

****

Kenneth D. Kerri, Project Director
John Brady, Co-Director

****

for the

Environmental Protection Agency
Office of Water Program Operations
Municipal Permits and Operations Division

First Edition, Grant No. T900494 (1976)
1987

OPERATOR TRAINING MANUALS IN THIS SERIES are available from Ken Kerri, California State University, Sacramento, 6000 J Street, Sacramento, CA 95819-2694, phone (916) 278-6142:

1. *OPERATION AND MAINTENANCE OF WASTEWATER COLLECTION SYSTEMS,* 2 Volumes,
2. *OPERATION OF WASTEWATER TREATMENT PLANTS,* 3 Volumes,
3. *TREATMENT OF WASTEWATER FROM ELECTROPLATING, METAL FINISHING AND PRINTED CIRCUIT BOARD MANUFACTURING,* 1 Volume,
4. *WATER TREATMENT PLANT OPERATION,* 2 Volumes,
5. *SMALL WATER SYSTEM OPERATION AND MAINTENANCE,* 1 Volume, and
6. *WATER DISTRIBUTION SYSTEM OPERATION AND MAINTENANCE,* 1 Volume.
7. *PRETREATMENT FACILITY INSPECTION,* 1 Volume (available 1988).

NOTICE

This manual is revised and updated before each printing based on comments from persons using this manual.

FIRST EDITION	
First Printing, 1976	5,000
SECOND EDITION	
First Printing, 1983	5,000
THIRD EDITION	
First Printing, 1987	5,000

Copyright 1987 by
Hornet Foundation, Inc.
California State University, Sacramento

PREFACE TO THE FIRST AND SECOND EDITIONS

The purposes of this wastewater collection system home study course are:

1. To develop new qualified wastewater collection system operators,
2. To expand the abilities of existing operators, permitting better service to both their employers and the public, and
3. To prepare operators for civil service and *CERTIFICATION EXAMINATIONS.*[1]

To provide you with the information needed to operate and to maintain wastewater collection systems as efficiently and effectively as possible, experienced wastewater collection system operators prepared the material in each chapter of this manual.

For many years the Water Pollution Control Federation, its member associations, state and local utility agencies, and colleges and universities have sensed a need for improvement in the dissemination of information on the operation and maintenance of wastewater collection systems. They have also felt a need for better training opportunities in this field. However, because of the lack of communication between the practical people doing the work in the field and the professional people in charge of publishing and training activities, the dissemination of information and training in the collection system field has been, until a few years ago, almost negligible compared to that in the wastewater treatment plant field.

Following completion of and the successful results from EPA's national field study training program, *OPERATION OF WASTEWATER TREATMENT PLANTS,*[2] a similar effort appeared desirable for wastewater collection system operators. In cooperation with the California Water Pollution Control Association, the project directors prepared and submitted a proposal to the Environmental Protection Agency for financial support through the Foundation of California State University, Sacramento. CWPCA President Robert Bernicchi requested the Presidents of the Water Pollution Control Federation's member associations to urge EPA to support this national effort to develop a training manual for wastewater collection system operators. Response from the member associations was quick, the need was documented, and EPA approval received. Chapters were written, presented at small informal seminars, reviewed by consultants and reviewers from throughout the United States, field tested by potential and experienced collection system operators, reviewed by the Environmental Protection Agency, and revised after each step in accordance with the suggestions and experiences gained from these sources.

The California Water Pollution Control Association would like to acknowledge the cooperation and assistance in review that it received from the Personnel Advancement Committee and the Wastewater Collection Systems Committee of the Water Pollution Control Federation during the development of this publication.

The project directors are indebted to the authors of each chapter and the many potential and experienced collection system operators who field tested and reviewed the material. Mr. F. J. Ludzack, National Training Center, Office of Water Program Operations, Environmental Protection Agency, offered many technical improvements. Dr. Elie Namour, author of EPA's "Manpower Manuals for Wastewater Collection Systems," reviewed the manpower aspects of the manual. Our Program Manager, Mr. Robert Rose, Chief, State and Local Training Activities Section, EPA, served as a valuable source of information and guidance. A special note of thanks is due to our typists, Ms. Charlene Arora and Mrs. Elaine Saika, who somehow managed to cope with illegible handwriting and unmeetable deadlines with smiles and perfect manuscripts. Illustrations were drawn by Mr. Martin Garrity. Some sketches and line drawings were prepared by George Gardin and Sue Hashimoto.

KENNETH D. KERRI
JOHN BRADY

1976

---

[1] *Certification examination. An examination administered by a state or professional association that wastewater collection system operators take to indicate a level of professional competence. In many states certification of wastewater collection system operators is voluntary. Current trends indicate that more states and employers will require wastewater collection system operators to be "certified" in the future.*

[2] *OPERATION OF WASTEWATER TREATMENT PLANTS, by Kenneth D. Kerri and Bill B. Dendy, California State University, Sacramento, 6000 J Street, Sacramento, California, 95819-2694.*

6

PREFACE TO THE THIRD EDITION

Collection system operators have always survived by their wits and ingenuity. Today operators are applying the most advanced technologies available to the operation and maintenance of wastewater collection systems. The TV technology used to inspect and record the status of collection systems is continually advancing. New instruments whose precision and reliability are improving over previous models are becoming available to make work in and around collection systems much safer. Personal computers are being used to inventory collection systems, maintain a history of the system, and schedule preventive maintenance when needed and before problems develop. Technology is allowing collection system operators to perform more and more tasks without having to enter manholes or sewers, thus reducing the risk of exposure to safety hazards.

Persons selected to work on this revision and expansion were recognized experts throughout the United States. Many of the collection system operators who successfully completed this course made helpful suggestions for improvement as they worked their way through the manual. Gay Kornweibel prepared the manuscript and took care of the administrative details. The efforts of everyone who contributed to the successful revision of this manual are sincerely appreciated.

1987 KENNETH D. KERRI

OBJECTIVES OF THIS MANUAL

Proper installations, inspections, operations, maintenance and repairs of wastewater collection, conveyance and treatment facilities have a significant impact on the operation and maintenance costs and effectiveness of these facilities. The objective of this manual is to provide wastewater collection system operators with the knowledge and skills where possible to effectively operate and to maintain collection systems, thus eliminating or reducing the following problems:

1. Health hazards caused by untreated wastewater flowing down streets and watercourses during stoppages and storms;
2. System failures that result from the lack of proper installation, inspection, preventive maintenance, surveillance and repair programs designed to protect the public's investment in these facilities;
3. Odors from the collection system, lift stations, and treatment plants caused by collection system problems;
4. Shock loads from the clearing of stoppages that affect wastewater treatment processes;
5. Corrosion damages to equipment and structures in collection systems and treatment plants;
6. Inflow and infiltration that use a valuable portion of the capacity of the facilities;
7. Noise pollution from collection systems (noisy manhole lids) and lift stations; and
8. Complaints from the public or local officials due to the unreliability of the collection system. These complaints result from constant system failures and create a poor public image of the agency that is supposed to be managing the system.

SCOPE OF THIS MANUAL

This manual contains information on:

1. What collection systems are expected to achieve,
2. Why wastewater collection systems must be properly operated and maintained,
3. What the collection system operator is expected to do to keep the collection system functioning as intended,
4. How to inspect and test newly constructed sewers and new and old wastewater collection systems,
5. How to locate and evaluate problems such as stoppages, leaks, odors and lift station failures,
6. Selection of procedures and equipment to correct identified problems and to minimize recurrence of problems and failures,
7. How to operate and maintain inspection and cleaning equipment,
8. Methods of selection and application of chemicals,
9. Procedures for operating, maintaining and repairing collection systems,
10. Instructions for operating, maintaining, troubleshooting and repairing collection system equipment and facilities such as lift stations,
11. How to evaluate the status of a collection system and to select the appropriate rehabilitation measures when necessary,
12. Techniques for recognizing hazards and developing safe procedures, and
13. How to organize and administer the operation and maintenance of wastewater collection systems.

Material contained in this manual furnishes you with information concerning situations encountered by most collection system operators regardless of whether they are located in the North, South, East or West, at sea level or in the mountains, in either humid or arid regions. These materials also provide you with an understanding of the basic operational and maintenance concepts for wastewater collection systems and with an ability to analyze and solve problems when they occur. Operation and maintenance programs for wastewater collection systems will vary with the age of the system, the extent and effectiveness of previous programs, and local conditions. You will have to adapt the information and procedures in this manual to your particular situation.

Technology is advancing very rapidly in the field of the operation and maintenance of wastewater collection systems. To keep pace with scientific advances, the material in this program must be periodically revised and updated. This means that you, the wastewater collection system operator, must be aware of new advances and recognize the need for continuous personal training reaching beyond this program. Training opportunities exist in your daily work experience, from your associates, and from attending meetings, workshops, conferences and classes.

SPECIAL NOTICE

All job titles or descriptions of duties of wastewater collection system operators in this manual are identified with "Standard Occupational Titles." We have tried to describe job titles and duties with words that reflect or describe actual tasks performed. These words were used to help you understand the jobs and duties of each person on a crew.

Describing our job titles according to "Standard Occupational Titles" will help you and your employer realize the knowledge, skills and traits you need to do your job. Use of "Standard Occupational Titles" helps operators prepare for and accept jobs throughout the United States because all of us are talking about the same job. If you work for a small agency, you may be expected to be a "jack-of-all-trades" and do many different types of jobs, regardless of your job title. Operators for a large agency may become a specialist in one or two tasks, but often are expected to be knowledgeable about and skilled at several jobs. The U.S. Employment Service prepared the "Standard Occupational Titles" and emphasizes that these titles "CANNOT BE CONSIDERED STANDARDS FOR SETTING WAGES OR HOURS, OR SETTLING JURISDICTIONAL MATTERS."

USES OF THIS MANUAL

This manual was developed to serve as a home-study course for collection system operators in remote areas or persons unable to attend formal classes either due to shift work, personal reasons or the unavailability of suitable classes. This home-study training program uses the concepts of self-paced instruction where you are your own instructor and work at your own speed. In order to certify that a person has successfully completed this program, an objective test is included at the end of each chapter.

Once collection system operators started using this manual for home study, they realized that it could serve effectively as a textbook in the classroom. Colleges and universities have used the manual as a text in formal classes often taught by foremen and supervisors. In areas where colleges were not available or were unable to offer classes in the operation and maintenance of wastewater collection systems, collection system operators and utility agencies joined together to offer their own courses using the manual.

Utility agencies have enrolled from three to over 70 of their collection system operators in this training program. A manual is purchased for each operator. A supervisor, foreman, or group of foremen are designated as instructors. These instructors help answer questions when the persons in the training program have questions or need assistance. The instructors grade the objective tests at the end of each chapter, record scores and notify California State University, Sacramento, of the scores when a person successfully completes this program. This approach avoids the long wait while papers are being graded and returned by CSUS.

This manual was prepared to help collection system operators operate and maintain their collection systems. Please feel free to use it in the manner which best fits your training needs and the needs of other collection system operators. We will be happy to work with you to assist you in developing your training program. Please feel free to contact

Ken Kerri, Project Director
Operation and Maintenance of Wastewater
Collection Systems
California State University, Sacramento
6000 J Street
Sacramento, California 95819-2694

Phone (916) 278-6142
or 278-6366

INSTRUCTIONS TO PARTICIPANTS IN HOME-STUDY COURSE

Procedures for reading the lessons and answering the questions are contained in this section.

To progress steadily through this program, you should establish a regular study schedule. For example many operators in the past have set aside two hours during two evenings a week for study.

The study material is contained in thirteen chapters and two appendices. Some chapters are longer and more difficult than others. For this reason, many of the chapters are divided into two or more lessons. The time required to complete a lesson will depend on your background, experience, and study habits. Some people may require an hour to complete a lesson, and some might require three hours, but that is perfectly all right. *THE IMPORTANT THING IS THAT YOU UNDERSTAND THE MATERIAL IN THE LESSON!* Each lesson is arranged for you to read a short section, write the answers to the questions at the end of the section, compare your answers against suggested answers; and then *YOU* decide if you understand the material sufficiently to continue or whether you should reread the section again. You will find that this procedure is slower than reading a typical textbook, but you will know and be able to use the information much better when you have finished the lesson.

Some discussion and review questions are provided following each lesson in some of the chapters. These questions review the important points you have covered in the lesson. At the end of each chapter, you will find an "objective test" containing true or false, multiple choice, fill in the blank, or match the answers types of questions. The purposes of this exam are to review the chapter and to give you experience in taking different types of exams.

MAIL TO THE PROGRAM DIRECTOR ONLY YOUR ANSWERS TO OBJECTIVE TESTS ON THE ANSWER SHEETS.

After you have completed the last objective test, you will find a final examination. This exam is provided for you to review how well you remember the material. You may wish to review the entire manual before you take the final exam. Some of the questions are essay-type questions which are used by some states and professional associations for higher-level certification examinations. After you have completed the final examination, grade your own paper and determine the areas in which you might need additional review before your next examination.

You are your own teacher in this program. You could merely look up the suggested answers at the end of each chapter or copy the answers from someone else, but you would not have given yourself a chance to understand the material. Consequently, you would not be able to apply the material to the operation and maintenance of your collection system nor recall it during an examination for certification or a civil service position.

YOU WILL GET OUT OF THIS PROGRAM WHAT YOU PUT INTO IT.

10

SUMMARY OF PROCEDURE

A. OPERATOR (YOU)

1. Read what you are expected to learn in each chapter (objectives of each chapter).
2. Read sections in lesson.
3. Write answers to questions at end of sections in your notebook. You should write the answers to the questions just like you would if these were questions on a test.
4. Compare your answers with suggested answers.
5. Decide whether to reread section or to continue with the next section.
6. Write answers to discussion and review questions at the end of lessons in the notebook.
7. Mark answers to objective test on answer sheet.
8. Mail answer sheet for objective test to project director.

Ken Kerri, Project Director
Operation and Maintenance of
Wastewater Collection Systems
California State University, Sacramento
6000 J Street
Sacramento, California 95819-2694

B. PROJECT DIRECTOR

1. Mails answer sheet for each chapter to student.
2. Corrects tests, answers any questions, and returns results to collection system operators.

C. ORDER OF WORKING LESSONS

To complete this program you will have to work all of the chapters. You may proceed in numerical order, or you may wish to work some lessons sooner. If you are working on a specific job such as pipeline cleaning, you may wish to read Chapter 6 after Chapter 2.

SAFETY IS A VERY IMPORTANT CHAPTER. Everyone working in and around wastewater collection systems must always be safety conscious. You must take extreme care with your personal hygiene to prevent the spread of disease to yourself and your family. Collection system operators may have to work in and near excavations, embankments (fills), washouts, below grade structures, traffic and other dangerous situations and equipment that can cause a serious disabling injury if the operator is not aware of the potential danger and does not exercise adequate precautions. Confined spaces such as manholes and wet wells may have harmful atmospheres such as toxic gases, explosive mixtures, or oxygen deficiencies. For these reasons, you may decide to work on Chapter 4, Safety Procedures, and Chapter 11, Safety Programs for Collection System Operators, before completing the other chapters.

D. COMPLETION

Following successful completion of this program, a Certificate of Completion will be sent to you. If you wish, the Certificate can be sent to your supervisor, the mayor of your town, or any other official you think appropriate. Some operators have been presented their Certificate at a City Council meeting, got their picture in the newspaper and received a pay raise. When you successfully complete the course, the Project Director will ask you how you would like your name to appear on your Certificate and if you would like the Cetificate sent directly to you, or to your supervisor or other municipal official.

COURSE OUTLINE

Volume I

CHAPTER	TOPIC	PAGE
1	The Wastewater Collection System Operator	1
2	Why Collection System Operation	13
3	Wastewater Collection Systems	23
4	Safe Procedures	109
5	Inspecting and Testing Collection Systems	175
6	Pipeline Cleaning and Maintenance Methods	255
7	Underground Repair	363
APPENDIX	Final Examination	425
	Collection System Words	431
	Applications of Arithmetic to Collection Systems	471
	Index	511

COURSE OUTLINE

Volume II

CHAPTER	TOPIC	PAGE
8	Lift Stations	
9	Equipment Maintenance	
10	Sewer Rehabilitation	
11	Safety Programs for Collection System Operators	
12	Administration	
13	Organization for System Operation and Maintenance	
APPENDIX	Final Examination	
	Collection System Words	
	Applications of Arithmetic to Collection Systems	
	Index	

TECHNICAL CONSULTANTS

First and Second Editions

John Carvoretto
Ira Cotton
George Gardner
William Garber
James Kenmir
Warren Prentice

TECHNICAL CONSULTANT

Third Edition

John Brady

CHAPTER 1

THE WASTEWATER COLLECTION SYSTEM OPERATOR

by

Walt Driggs

TABLE OF CONTENTS

Chapter 1. The Wastewater Collection System Operator

Page

OBJECTIVES . . . 3

1.1 Let's Start Learning . . . 4

1.2 What is a Wastewater Collection System? . . . 4

1.3 What is Meant by Operation and Maintenance of Wastewater Collection Systems? . . . 4

1.4 What Does a Collection System Operator Do? . . . 7

1.5 Who Hires Collection System Operators? . . . 7

1.6 Where Do Collection System Operators Work? . . . 8

1.61 On the Job . . . 8

1.62 In the City and In the Country . . . 8

1.7 What Pay Can a Collection System Operator Expect? . . . 8

1.8 What Does It Take To Be A Collection System Operator? . . . 8

1.9 Your Personal Training Course . . . 9

Suggested Answers . . . 10

OBJECTIVES

Chapter 1. THE WASTEWATER COLLECTION SYSTEM OPERATOR

At the beginning of each chapter in this manual you will find a list of *OBJECTIVES*. The purpose of this list is to stress those topics in the chapter that are most important. Contained in the list will be items you need to know and skills you must develop to operate, to maintain, and to repair your wastewater collection system as efficiently and safely as possible.

After completion of Chapter 1 you should be able to do the following:

1. Explain the type of work done by collection system operators,
2. Describe where to look for jobs in this profession, and
3. Know how to learn how to do the jobs performed by collection system operators.

CHAPTER 1. THE WASTEWATER COLLECTION SYSTEM OPERATOR

Chapter 1 is prepared especially for new or potential wastewater collection system operators. If you are an experienced sewer maintenance person or wastewater collection system operator, you may find some new viewpoints in this chapter.

1.1 LET'S START LEARNING

I know that there are some of you working in the wastewater collection profession who feel you are the forgotten person due to lack of available books to help you improve yourself. Admittedly many books have been written by and for engineers on wastewater collection systems, but very few have been written by and for collection system operators. There are also those of you who are just starting out in this field. We hope this manual will help all of you in your attempts to improve your knowledge of the operation and maintenance of wastewater collection systems. We, the authors, dedicate ourselves to opening the eyes of those responsible for the collection and conveying of wastewater to make them more aware of the need for adequate equipment and good operation and maintenance practices.

Some of you may be called sewer workers. Today workers in wastewater collection may be called maintenance personnel or TV system operators. Throughout this manual people working with wasterwater collection systems are called *COLLECTION SYSTEM OPERATORS*. By using words that better describe our jobs, we can improve our public image and upgrade our profession. The Environmental Protection Agency considers us to he in the business of operating and maintaining wastewater collection systems. The wastewater is usually collected and conveyed in sewer pipes. If you find words or terms you don't understand as you progress through this manual, try looking up their meaning in the Appendix, Collection System Words, at the end of this manual.

1.2 WHAT IS A WASTEWATER COLLECTION SYSTEM?

A wastewater collecton system gathers the used water from our homes and businesses and conveys it to a wastewater treatment plant (Figure 1.1). This water may come from the kitchens or processes of businesses and industries. Sometimes groundwater, surface water and storm water may be present too. The collection system includes the gravity sewers, force mains, manholes, pumping equipment and other facilities that collect and convey the water to a wastewater treatment plant. Collection systems designed solely for storm waters usually convey these waters to streams, rivers, lakes or the ocean. Details on the parts of wastewater collection systems are described in Chapter 3.

1.3 WHAT IS MEANT BY OPERATION AND MAINTENANCE OF WASTEWATER COLLECTION SYSTEMS?

Operation and maintenance (O & M) of wastewater collection systems is similar to the O & M program of any other utility. The facilities should be kept in good operating condition. We would not be satisfied if the water company that serves our homes did not deliver water every time we turn the handle of a faucet. The same goes for the gas company that supplies gas to heat our homes. We don't want excuses why the gas or water delivery system has failed. We expect to have all the gas and water we want when we need it. Recall how annoyed we become if our phone doesn't work? We wonder why the phone company can't keep the phone service working all the time.

What happens when wastewater collection systems fail? Here are some of the problems that can develop.

1. A drain in the kitchen, bathroom or basement fails to work, but the other drains in the house or building work properly. If this failure is noticed quickly, the particular basin served by the drain may contain the water or drainage until the faucet is shut off or the drain is unplugged. The householder may have a plunger, reamer or chemical cleaner and know how to use these methods to clear the stoppage. This is a local problem and can be quickly resolved. If the householder can't clear the stoppage, it's still a local problem. A plumber can clear the stoppage, but this costs money and the stoppage is not cleared immediately.

2. A stoppage develops in a household drainage system when an occupant has started a water using appliance or fixture. The occupant walks away to visit, use the phone, or enjoy the outdoors. While the occupant is gone, quite a mess can develop. Water continues to flow from the appliance or fixture unless it is on a timed cycle. The basin served by the stopped drain overflows and the floor becomes a drainage route. Rugs and

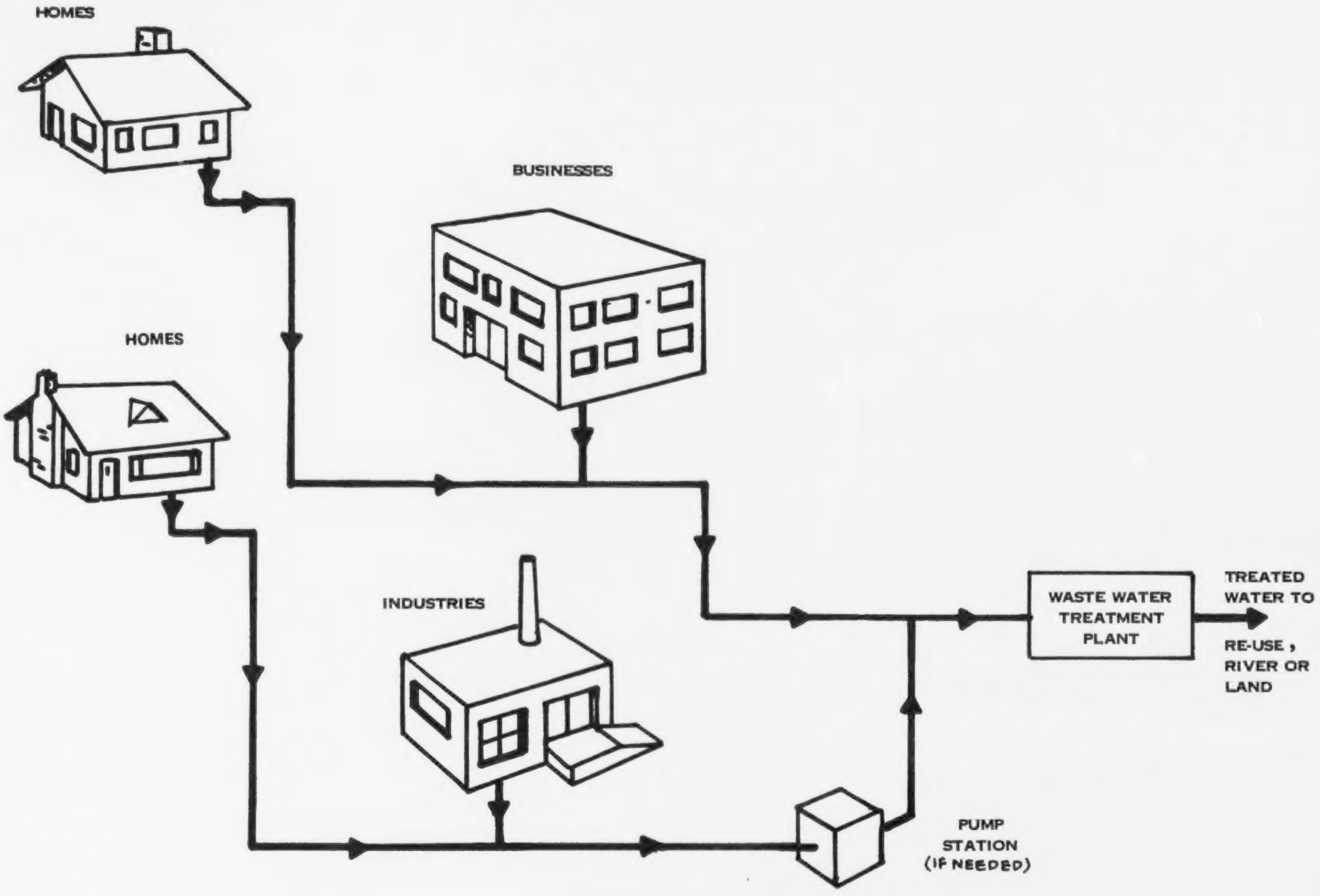

HOMES
BUSINESSES
HOMES
INDUSTRIES
WASTE WATER TREATMENT PLANT
TREATED WATER TO
RE-USE , RIVER OR LAND
PUMP STATION (IF NEEDED)

Fig 1.1. Contributors to wastewater collection systems

carpets get pretty soggy. If a doorway or floor drain doesn't allow drainage, the repair and cleanup job becomes very extensive and expensive. However, this is still a local or occupant problem.

3. A stoppage in the floor drain system in the basement floor becomes very serious, especially if it isn't noticed quickly. All drainage or feeder lines to the floor drains contribute to the flooding. The water supply to the home or building must be shut off to limit damage until the stoppage is removed. If you have a friendly neighbor, you can still get the necessary houshold services until the situation is corrected by your efforts or the efforts of a plumber. If you fail to shut off the water supply soon enough, you may have a flooded basement. When this happens the pilot lights for your home or space heater and water heater become flooded. All electrical appliances contribute to an expensive and dangerous situation.

4. If a stoppage develops beyond the property line, it usually does not have to be cleared by the occupant or by a plumber. When flooding occurs from the lowest drains in a house or building, contact occupants of adjacent buildings with lower floor drains in an attempt to locate the area of the stoppage. Determine if these people are experiencing slow drainage or backflow. If they are, phone the sewer maintenance department and give them all of the available information you have on location, extent and nature of the problem.

   The sewer maintenance department will start corrective action as soon as possible. Current workload, available staffing and equipment, priorities related to their workload, extent of damage from stoppage and area affected will enter into the quickness of their response to each particular problem. First they have to locate the stoppage and determine what can be done about it. They may start temporary pumping or alternate routing of wastewater to relieve the drainage problem above the obstruction. If it is a simple stoppage, it may be promptly cleared. A major structural failure of a pipe may require some time to repair.

   Some agencies have a policy of encouraging the public to call them whenever a stoppage of any kind develops. The idea behind this policy is that if the stoppage is in the main line, the agency wants to clear it as soon as possible in order to minimize damage to homes and overflow from manholes.

Let's compare implications of service interruptions of common public services such as telephone, gas, water supply, electrical supply, and wastewater collection systems. We know each of these systems occasionally fails. Whenever any one of these services fails, a nuisance condition develops that tends to produce a highly emotional response depending upon the individual and the situation.

A telephone failure means going to the nearest working telephone to report the problem. The telephone service people may find the cause of the problem in a central office or they may send repair personnel to your home. You may miss a few phone calls or be inconvenienced. Usually you can reach a nearby working phone.

The water supply may stop as a result of a line break in your home or beyond your property line. If the failure occurs on your property, you shut off the water supply at the meter or curb and call a plumber. If the failure occurs beyond your meter or curb, you call the water supply service agency. They will correct their problem as soon as possible, depending upon the nature and extent of the service interruption and what is required to restore service. In the meantime you may have to depend on a friendly neighbor for an alternate water supply service. There may be water damage, but hopefully a serious washout will not be caused by a major line breakage.

Natural gas service interruption may be the result of a stoppage or leaks in the delivery system. Gas is odorized to provide a warning if a leak occurs. Proceed with caution at any time there is any suspicion of gas leakage. Explosive limits for natural gas in air are from about 1 to 33 percent gas. All this mixture needs is a spark to cause a fire or an explosion. A defective heater, heater controls, flame blowout, or leaking pipes all can provide pockets of gas. When a gas leak is suspected or discovered, ventilate the area, guard against a spark (absolutely no smoking), and call the municipal gas service immediately. Explosion and/or fire are serious hazards. Even a small one causes a messy cleanup job. A major explosion or fire may result in an injury or loss of life, and extensive property damage or destruction. Preventive maintenance is the only safe and sane course of action.

Electric power interruption affects lighting, power, automatic controllers, alarms and safety devices. The householder must use candles (if there are no gas leaks), flashlights, manual controls and do-it-yourself ingenuity. Refrigerators, freezers and air conditioners don't work. For a short time the refrigerator and freezer will protect their contents if they are kept closed. The electric service agency will take action as soon as they are notified, but they are not magicians. They must have time to locate the problem, gather staff and equipment, and repair the problem. The failure may be due to a fuse or thermal breaker in the house caused by defective wiring or appliances. A major brownout or blackout in the area could be caused by central or substation damage or failure. Line damage can be repaired relatively rapidly if only one or two lines are involved. A major ice or wind storm can affect many lines and a long time will be required to restore service even with imported maintenance crews and equipment.

The interruption of wastewater collection service, like drinking water service, generally promotes a more emotional response than failures of other utilities. Possibly this is because the customers have been underfunding collection system maintenance and repairs for years and want the municipality to make it disappear on a "free ride" basis. Collection system maintenance and repair is an expensive operation and is usually a low priority item on the municipal budget when compared with streets, public buildings, parks, schools, police and fire protection that can be seen everyday by the public.

What happens?

When a stoppage develops or flow in excess of the sewer capacity cannot escape, the wastewater starts to back up in the sewers and flows out manholes into the streets or through the lowest elevation basement drains or house drains connected to the sewer. Hoseholds at higher elevations may experience no problems because their drains are above the elevation of the stoppage and the backed-up wastewater. Actually these homes are contributing to the basement backflow in the lower elevation drains. The lowest households upstream from the stoppage receive the collected backflow. A stinking mess develops that creates a health, odor, and filth problem.

The low section households can shut off their water supply, but the sewer backflow continues from the higher elevation connections. Flooded basements tend to cause cross connections between the water supply and the sewer by allowing wastewater to reach water supply faucets, thus possibly contaminating the public water supply. When flooding of basements occurs, electric and gas utilities must be shut off immediately. Telephone lines become jammed because more than 10 to 15 percent of the users in the area are trying to complain and get the situation corrected. Any utility interruption is a serious inconvenience and a potential hazard. A collection system failure creates a health and sanitation hazard and possibly interrupts all of the utilities serving the affected area. Residents of affected buildings usually must find alternate shelter and services somewhere else until service can be restored to the affected area and the individual households can be cleaned, repaired or replaced.

The wastewater collection system operator is a key individual with a major affect upon the health and general well-being of the community. Recognition of this status is being improved, but it has a long way to go. Better trained and motivated individuals working for collection system agencies are essential to present a better case for improved priorities and public recognition.

1.4 WHAT DOES A COLLECTION SYSTEM OPERATOR DO?

Simply described, collection system operators keep the system working. They inspect the system to keep the wastewater flowing today and in the future. Physically they have manual and power operated equipment to help them with the job. Some of the jobs they do include inspecting and/or installing new service connections, using closed circuit television to inspect sewers where there is no other way to observe the system, cleaning sewers, removing stoppages in sewers, maintaining equipment, and repairing lines, equipment and facilities. From an overall viewpoint, collection system operators are responsible for the collection of wastewater and the conveying of the wastewater to a treatment plant. The better the job collection system operators do, the more effective a wastewater treatment plant can do its intended job.

1.5 WHO HIRES COLLECTION SYSTEM OPERATORS?

Operators paychecks usually come from a city, sanitation district, or private utility company. They also may be employed by a sewer cleaning contractor. Either way, they are playing an important part in maintaining the good health of the community. People living in the community who discharge their wastewaters to the collection system are the people for whom the collection system operators are really working.

QUESTIONS

Place an X by the *CORRECT ANSWER OR ANSWERS* (more than one answer may be correct). After you have answered all the questions, compare your answers with those given at the end of this chapter on page 10. Reread any sections you do not understand and then proceed to the next section. You are your own teacher in this training program, and *YOU* should decide when you understand the material and are ready to continue with new material.

EXAMPLE

This is a training manual on:

________1. Arithmetic

________2. Engineering

____X____3. Wastewater Collection Systems

________4. Truck Driving

1.2A The main purpose of a wastewater collection system is to gather:

________1. Spent or used water from our homes and businesses.

________2. Irrigation water from fields.

________3. Waste material from junk yards.

________4. Drinking water from lakes.

1.3A Why must wastewater collection systems be properly operated and maintained?

________1. So wastewater won't flood our homes.

________2. To keep your employer from being sued for damages caused by wastewater.

________3. So collection system operators will have extra time to repair streets.

________4. To keep the collection system's office phones from being busy all of the time.

Using TV to inspect sewer pipes?

1.4A What does a collection system operator do?

________1. Keeps the collection system working.

________2. Repairs underground pipes and manholes.

________3. Removes stoppages.

________4. Cleans sewers.

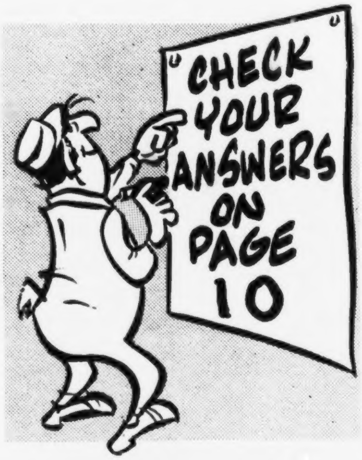
________5. Maintains collection system equipment.

1.5A Who hires collection system operators?

________1. City.

________2. Sanitation district.

________3. Pipeline cleaning contractor.



1.6 WHERE DO COLLECTION SYSTEM OPERATORS WORK?

1.61 On the job

You may be surprised, but if you are working for an agency or contractor that is up to date, you will spend very little time in a sewer or manhole. Modern technology has developed equipment and procedures to reduce unpleasant tasks as much as possible. Most of the work is done from "topside." But if you must work underground, (below the ground surface) learn to do it safely.

Throughout this manual, you will learn how to protect yourself and your fellow operators whether you are working underground or topside. If you must work underground or in confined spaces in the collection system, be sure to follow your supervisor's instructions. If you or your supervisor have questions or doubts, your supervisor should consult with an experienced associate or your agency or local safety officer for rules and regulations for your safety. If you work for a small contractor or agency that does not have a safety officer, consult with your state or federal OSHA (Occupational Safety and Health Act) safety people *BEFORE* you take a chance.

Your employer wants you to be a hit, but not a smash (*WORK SAFE*).

1.62 In the City and In the Country

Jobs are available for wastewater collection system operators wherever people live and discharge the wastewater from their homes into a common collection system. From the mountains to the sea and everywhere in between are found wastewater collection systems. You have the opportunity to work for either a small or large agency. The choice is yours if you can convince an employer that you have the knowledge and skills necessary to do the job.

1.7 WHAT PAY CAN A COLLECTION SYSTEM OPERATOR EXPECT?

In dollars? Prestige? Job satisfaction? Community service? In opportunities for advancement? By whatever scale you use, returns are what you make them. If you choose a large municipality, the pay is good and advancement prospects are tops. Choose a small town or contractor and the pay may not be as good, but job satisfaction, freedom from time-clock hours, community service, and prestige may well add up to outstanding personal achievement. If you have the ability and the opportunity, you can make this field your career and advance to the top. Many of these positions are or will be represented by a union that will try to obtain higher pay and other benefits for you. Total reward depends on you and how *YOU APPLY YOURSELF.*

1.8 WHAT DOES IT TAKE TO BE A COLLECTION SYSTEM OPERATOR?

DESIRE. First you must choose to enter this profession. You can do it with a grammar school, a high school, or a college degree. While some jobs will always exist for manual labor, the real and expanding need is for *QUALIFIED OPERATORS.* You must be willing to study and take an active role in upgrading your capabilities. The high velocity cleaners and closed circuit television inspection units are examples of the costly and sophisticated equipment used by our profession today. Employers will not risk their investment by allowing unqualified people to operate this complex equipment.

What will be your job title? This will depend on how your employer classifies job titles. Today a sewage treatment plant operator may be called a water quality control plant operator, a janitor may be called a custodian, and a garbage man a refuse collector. All of these new job titles were developed to make the job more acceptable to the general public. Whether you are called a wastewater collection system operator or a sewer maintenance operator, you should be proud of where you work and of your job. You can become a better qualified professional operator; ready for advancement by increasing your knowledge today.

Obviously this manual cannot train you to be an expert equipment operator, familiar with each handle on all machines, but it will tell you how to select equipment, what it can and can't do, and how to keep records of your activities. All of these factors are essential to proper operation and maintenance of your collection system.

This training manual can be your start towards a future filled with a different challenge each day and job satisfaction that most people never achieve and enjoy.

1.9 YOUR PERSONAL TRAINING COURSE

Beginning on this page you are starting on a training course which has been carefully prepared to allow you to improve your knowledge and ability to operate and to maintain wastewater collection systems.

You will be able to proceed at your own pace; you will have an opportunity to learn a little or a lot about each topic. The manual has been prepared this way to fit the various needs of collection system operators, depending on the size and type of collection system for which you are responsible. To study for certification and civil service exams you may have to cover most of the material in this manual. You will never know everything about wastewater collection systems and the equipment and procedures available for operation and maintenance, but you can begin to answer some very important questions about how, why, and when certain things happen in collection systems. You can also learn how to manage your collection system to minimize stoppages, odors, failures, and costs to taxpayers in the long run.

This training course is not the only one available to help you improve your abilities. Some state water pollution control associations, community colleges and universities offer training courses on both a short - and long - term basis. Many state, local and private agencies have conducted training programs and informative seminars.

Libraries can be an excellent source of useful journals and books. Many very helpful publications have been developed and distributed by the:

WATER POLLUTION CONTROL FEDERATION
601 Wythe Street
Alexandria, Virginia 22314

When ordering publications from the Water Pollution Control Federation, include your Member Identification Number in order to obtain the member discount.

WPCF publications listed below will provide interesting reading and additional information. All prices listed in this manual are the most recent prices available when the manual was printed.

	WPCF Members	Others
1. Manual of Practice (MOP) 1. *SAFETY AND HEALTH IN WASTEWATER SYSTEMS*	$24.00	$32.00
2. MOP 3. *REGULATION OF SEWER USE.*	4.50	6.00
3. MOP 7. *OPERATION AND MAINTENANCE OF WASTEWATER COLLECTION SYSTEMS.*	11.50	15.00
4. MOP 9. *DESIGN AND CONSTRUCTION OF STORM AND SANITARY SEWERS.*	17.00	21.50

Note that Water Pollution Control Federation members can buy publications at lower prices. You can join the WPCF by writing to the Water Pollution Control Federation. The WPCF can help you contact your own state and local water pollution control association. These professional organizations can offer you many helpful training opportunities and educational materials when you join and actively participate with your associates in the field.

QUESTIONS

Write your answers in a notebook. When you *WRITE* your answers, you are helping yourself *LEARN AND REMEMBER* the answer. Compare your answers with the suggested answers on page 10.

1.6A Where do collection system people work on the job?
1.6B Who can help you determine safe procedures for working underground?
1.8A What does it take to be a collection system operator?
1.9A Where else besides this manual could you look for information and help to learn more about wastewater collection systems?

SUGGESTED ANSWERS

CHAPTER 1. THE WASTEWATER COLLECTION SYSTEM OPERATOR

You are not expected to have the exact answer suggested for questions requiring written answers, but you should have the correct idea.

Answers to questions on pages 7 and 8.

1.2A 1. Spent or used water from our homes and business.

1.3A 1. So wastewater won't flood our homes.
2. To keep your employer from being sued for damages caused by wastewater.

1.4A 1. Keeps the collection system working.
2. Repairs underground pipes and manholes.
3. Removes stoppages.
4. Cleans sewers.
5. Maintains collection system equipment.

1.5A 1. City.
2. Sanitation district.
3. Pipeline cleaning contractor.

Answers to questions on page 9.

1.6A On the job collection system people work both topside and underground in manholes and sewers. Modern technology is continually developing equipment and procedures to make our job more pleasant and easier, as well as help us do a better job.

1.6B Your supervisor, an experienced associate, or your agency or local safety officer or a state or federal safety officer can help you determine safe procedures for working underground. This manual also outlines safe procedures.

1.8A *DESIRE* is the main requirement to be a collection system operator. Also you have to be willing to study and upgrade your capabilities.

1.9A To learn more information and gain help regarding wastewater collection systems, contact the Water Pollution Control Federation, state and local associations, state pollution control training agencies, colleges, and universities. Libraries can be an excellent source of useful journals and books.

HOW TO WORK THE OBJECTIVE TESTS

At the end of each chapter is an objective test.

1. You have been provided with a special answer sheet for each chapter. Be sure you follow the special directions provided with the answer sheets. If you lose an answer sheet or have any problems, please notify the Project Director.

2. Mark your answers on the answer sheet with a dark lead pencil. Do not use ink. Neatly erase any errors.

   Questions 1 through 3 are true or false questions. If a question is true, then mark Column 1, and if false mark Column 2. The correct answer to Question 1 is false; therefore, place a mark in Column 2.

   Questions 4 through 11 are multiple choice. Question 8 has three correct answers (1, 3 and 5). Therefore, you should place a mark under Columns 1, 3 and 5 on the answer sheet.

   Please mark your answers in your notebook for your record because answer sheets will not be returned to you.

3. Mail your answer sheet to the Project Director immediately after you have completed the test.

4. Answer sheets may be folded (but not into more than three equal parts) and mailed in a 4 × 9½ standard white envelope.

Please provide us with any *COMMENTS* that could help us improve the chapter. We would appreciate your comments and suggestions regarding:

a. Clarity and content of chapter,
b. Clarity and content of questions, and
c. Any words you did not understand.

Please write your comments on extra sheets other than the answer sheet. Mail your answer sheet and comments to:

Ken Kerri
California State University, Sacramento
6000 J Street
Sacramento, California 95819

OPERATION AND MAINTENANCE OF WASTEWATER COLLECTION SYSTEMS

IMPORTANT

PLEASE READ INSTRUCTIONS ON REVERSE SIDE BEFORE COMPLETING THIS FORM.

OFFICE USE ONLY
DO NOT MARK ●

Name: ______________________________
Last First MI

Address: ______________________________

____
City State Zip Code

Mail to:
Professor Kenneth Kerri
California State University, Sacramento
6000 Jay Street
Sacramento, California 95819

SOCIAL SECURITY NUMBER									CHAPTER NUMBER	
0	0	0	0	0	0	0	0	0	0	0
1	1	1	1	1	1	1	1	1	1	1
2	2	2	2	2	2	2	2	2	2	2
3	3	3	3	3	3	3	3	3	3	3
4	4	4	4	4	4	4	4	4		4
5	5	5	5	5	5	5	5	5		5
6	6	6	6	6	6	6	6	6		6
7	7	7	7	7	7	7	7	7		7
8	8	8	8	8	8	8	8	8		8
9	9	9	9	9	9	9	9	9		9

FOLD -

IMPORTANT DIRECTIONS FOR MARKING ANSWERS

Use black lead pencil only (# 2 or softer).
Make heavy black marks that fill the circle completely.
Erase clearly any answer you wish to change.
Make no stray marks on this answer sheet.

1. MULTIPLE CHOICE QUESTIONS: Fill in the correct answers. If 2 and 3 are correct for question 1, mark:

	1	2	3	4	5
1	Ⓣ	●	●	○	○

2. TRUE–FALSE QUESTIONS: If true, fill in the circle in column 1; if false, fill in column 2. If question 3 is true, mark:

	1	2	3	4	5
3	●	Ⓕ	○	○	○

EXAMPLE

SOCIAL SECURITY NUMBER									CHAPTER NUMBER	
1	2	3	4	5	6	7	8	9	0	1
0	0	0	0	0	0	0	0	0	●	0
●	1	1	1	1	1	1	1	1	1	●
2	●	2	2	2	2	2	2	2	2	2
3	3	●	3	3	3	3	3	3	3	3
4	4	4	●	4	4	4	4	4		4
5	5	5	5	●	5	5	5	5		5
6	6	6	6	6	●	6	6	6		6
7	7	7	7	7	7	●	7	7		7
8	8	8	8	8	8	8	●	8		8
9	9	9	9	9	9	9	9	●		9

NCS Trans Optic F 6297 54321

FOLD -

SAMPLE

	1	2	3	4	5		1	2	3	4	5		1	2	3	4	5		1	2	3	4	5		1	2	3	4	5		1	2	3	4	5
1	Ⓣ	●	○	○	○	11	Ⓣ	Ⓕ	○	○	○	21	Ⓣ	Ⓕ	○	○	○	31	Ⓣ	Ⓕ	○	○	○	41	Ⓣ	Ⓕ	○	○	○	51	Ⓣ	Ⓕ	○	○	○
2	Ⓣ	Ⓕ	○	○	○	12	Ⓣ	Ⓕ	○	○	○	22	Ⓣ	Ⓕ	○	○	○	32	Ⓣ	Ⓕ	○	○	○	42	Ⓣ	Ⓕ	○	○	○	52	Ⓣ	Ⓕ	○	○	○
3	Ⓣ	Ⓕ	○	○	○	13	Ⓣ	Ⓕ	○	○	○	23	Ⓣ	Ⓕ	○	○	○	33	Ⓣ	Ⓕ	○	○	○	43	Ⓣ	Ⓕ	○	○	○	53	Ⓣ	Ⓕ	○	○	○
4	Ⓣ	Ⓕ	○	○	○	14	Ⓣ	Ⓕ	○	○	○	24	Ⓣ	Ⓕ	○	○	○	34	Ⓣ	Ⓕ	○	○	○	44	Ⓣ	Ⓕ	○	○	○	54	Ⓣ	Ⓕ	○	○	○
5	Ⓣ	Ⓕ	○	○	○	15	Ⓣ	Ⓕ	○	○	○	25	Ⓣ	Ⓕ	○	○	○	35	Ⓣ	Ⓕ	○	○	○	45	Ⓣ	Ⓕ	○	○	○	55	Ⓣ	Ⓕ	○	○	○
6	Ⓣ	Ⓕ	○	○	○	16	Ⓣ	Ⓕ	○	○	○	26	Ⓣ	Ⓕ	○	○	○	36	Ⓣ	Ⓕ	○	○	○	46	Ⓣ	Ⓕ	○	○	○	56	Ⓣ	Ⓕ	○	○	○
7	Ⓣ	Ⓕ	○	○	○	17	Ⓣ	Ⓕ	○	○	○	27	Ⓣ	Ⓕ	○	○	○	37	Ⓣ	Ⓕ	○	○	○	47	Ⓣ	Ⓕ	○	○	○	57	Ⓣ	Ⓕ	○	○	○
8	●	Ⓕ	●	○	●	18	Ⓣ	Ⓕ	○	○	○	28	Ⓣ	Ⓕ	○	○	○	38	Ⓣ	Ⓕ	○	○	○	48	Ⓣ	Ⓕ	○	○	○	58	Ⓣ	Ⓕ	○	○	○
9	Ⓣ	Ⓕ	○	○	○	19	Ⓣ	Ⓕ	○	○	○	29	Ⓣ	Ⓕ	○	○	○	39	Ⓣ	Ⓕ	○	○	○	49	Ⓣ	Ⓕ	○	○	○	59	Ⓣ	Ⓕ	○	○	○
10	Ⓣ	Ⓕ	○	○	○	20	Ⓣ	Ⓕ	○	○	○	30	Ⓣ	Ⓕ	○	○	○	40	Ⓣ	Ⓕ	○	○	○	50	Ⓣ	Ⓕ	○	○	○	60	Ⓣ	Ⓕ	○	○	○

OBJECTIVE TEST

Chapter 1. THE WASTEWATER COLLECTION SYSTEM OPERATOR

Please mark the correct answers on the answer sheets as directed at the end of Chapter 1. There may be more than one correct answer to many of the questions.

1. A wastewater collection system gathers
    1. Leaves from yards.
    2. Papers from computer systems.
    3. Used water from homes.
    4. Used water from industries.
    5. Wastes from agriculture.
2. Wastewater collection systems include
    1. Force mains.
    2. Gravity sewers.
    3. Manholes.
    4. Outfalls.
    5. Treatment plants.
3. Operation and maintenance of wastewater collection systems means keeping the
    1. Electrical power supply available without failures.
    2. Facilities in good operating condition.
    3. Gas supplies to heat our homes.
    4. Phones in working order.
    5. Water flowing out of the taps.
4. What can happen when collection systems fail?
    1. Health, odor and filth problems can develop.
    2. Stinking messes can occur.
    3. Stoppages can develop in a sewer.
    4. Wastewaters can backup in sewers.
    5. Wastewater can flow out manholes.
5. Sewer maintenance departments will start corrective actions to clear a stoppage as soon as possible based on
    1. Available staffing and equipment.
    2. Current workload.
    3. Extent of damage resulting from stoppage.
    4. Hydraulic loading on wastewater treatment plant.
    5. Priorities related to workload.
6. What happens when a sewer backs up and floods basements or homes?
    1. A cross connection between the water supply and the sewer develops.
    2. A health and sanitation hazard develops.
    3. Electric and gas utilities must be shut off immediately.
    4. There is no resulting impact on telephone service.
    5. Wastewater can contaminate a public water supply.
7. What does a collection system operator do?
    1. Clean sewers.
    2. Install new service connections.
    3. Keep wastewater flowing in the system.
    4. Remove stoppages from sewers.
    5. Use closed circuit television to inspect sewers.
8. Collection system operators are hired by
    1. Cities.
    2. Phone companies.
    3. Power companies.
    4. Private utility companies.
    5. Sanitation districts.
9. A collection system operator can learn or determine safe procedures for working in confined spaces from
    1. Experienced collection system operators.
    2. Safety officers.
    3. State or federal OSHA safety people.
    4. Supervisors.
    5. This manual.
10. What does it take to become a collection system operator? Select the best answer.
    1. A college degree.
    2. Ability to do arithmetic.
    3. Desire.
    4. Knowing how to work in wastewater.
    5. Understanding of flow hydraulics.
11. The word wastewater is used instead of sewage to
    1. Become in step with hi-tech terminology.
    2. Comply with federal grant funding requirements.
    3. Help the public understand the need for trained operators.
    4. Improve our public image.
    5. Upgrade our profession.
12. Where can collection system operators look for more information and training courses to improve themselves?
    1. Colleges and universities.
    2. Federal, state, and local water pollution control agencies.
    3. Libraries.
    4. State and local water pollution control associations.
    5. Water Pollution Control Federation.

END OF OBJECTIVE TEST

CHAPTER 2

WHY COLLECTION SYSTEM OPERATION AND MAINTENANCE?

by

Walt Driggs

TABLE OF CONTENTS

Chapter 2. WHY COLLECTION SYSTEM OPERATION AND MAINTENANCE?

Page

OBJECTIVES 15

2.1 Statement of the Problems 16

2.2 Why Have Collection Systems? 17

2.3 Comparisons of Collection Systems 17

  2.31 Highway and Street Comparison 18

  2.32 Traffic Signal Comparison 18

  2.33 Railroad Crossing Comparison 18

2.4 Why Operation and Maintenance of Your Wastewater Collection System? 18

  2.41 What is Operation and Maintenance? 18

  2.42 How to Tell When You Need To Do A Better Job 18

2.5 The Cost of Your Wastewater Collection System 18

2.6 The Wastewater Collection System Doctor 19

2.7 Summary 19

Suggested Answers 20

OBJECTIVES

Chapter 2. WHY COLLECTION SYSTEM OPERATION AND MAINTENANCE?

After completion of Chapter 2 you should be able to do the following:

1. Describe the problems of operating and maintaining a wastewater collection system,
2. Justify the need to operate and maintain the system, and
3. Tell what collection systems are expected to achieve.

CHAPTER 2. WHY COLLECTION SYSTEM OPERATION AND MAINTENANCE?

2.1 STATEMENT OF PROBLEMS

Eric Hoffer has said, "One's capacity to endure is directly related to the quality of his maintenance." Certainly this is true of wastewater collection systems. Preventive maintenance is talked about, but seldom practiced by some agencies. Decades of neglect, or grossly inadequate maintenance of some systems, are two reasons why wastewater collection systems now require over 12.8 billion dollars worth of rehabilitation and upgrading between now and 2005 and at a time when the economy can ill afford the cost.[1]

How did this come about?

1. Wastewater collection systems were engineered as *GRAVITY FLOW*[2] sewers with inadequate flow capacities for the area served or for the unexpected population growth.

2. Collection systems were not installed as designed. Problems are caused by faulty construction, poor inspection and low-bid short cuts.

3. Little thought was given to the fact that sewers, although made of permanent material, could be considered only as permanent as the joint. Earth movement, vibration from traffic, settling of structures and construction disturbance (all occur from time to time) require a flexible pipe material or joint that can maintain tightness, yet joints were made rigid.

4. Not enough scientific knowledge existed or was available to designers about potential damage to pipe joints by plant roots. Although root intrusion into sewers was age-old, it was assumed that if the joint was watertight, it would be roottight. People did not realize that roots would be attracted by moisture and nutrient vapor unless the joints were vaportight (which means airtight).

   Roots can enter a pipe joint or walls microscopically (through extremely small holes or cracks); thus, open or leaking joints are not necessary for root intrusion in collection systems.

   Collection system environments are ideal for root growth. In this environment, roots enter, expand and open joints and cracks. Root growth is a principal cause of pipe damage that allows *INFILTRATION*,[3] *INFLOW*[4] and *EXFILTRATION*.[5] This creates a major concern for health and pollution control authorities because of wastewater treatment plant overload and groundwater pollution.

5. The out of sight, out of mind nature of the wastewater collection system. Local taxpayers have invested more money in underground sewers than in all the structures above ground owned by their local government. Why has this great taxpayer investment been so grossly neglected? Because it is out of sight, and so, out of mind. Some cities spend more money repairing and replacing sidewalk sections because of earth movement and tree-root damage, than on preventive maintenance of wastewater collection systems.

6. Many collection systems are maintained by a department charged with street, sidewalk, storm drain, and sometimes water utility maintenance. Now, I leave it to you to guess where the money is spent. Money is usually spent where the taxpayer can see it, especially

---

[1] *"1986 Needs Survey, Cost Estimates for Construction of Publicly-Owned Wastewater Treatment Facilities," U.S. Environmental Protection Agency, Office of Water Programs, Municipal Construction Division, Washington, D.C., 1987.*

[2] *GRAVITY FLOW. Water or wastewater flowing from a higher elevation to a lower elevation due to the force of gravity. The water does not flow due to energy provided by a pump. Wherever possible, wastewater collection systems are designed to use the force of gravity to convey waste liquids and solids.*

[3] *INFILTRATION (pronounced IN-fill-TRAY-shun). The water entering a sewer system and service connections from the ground. Defective pipes, pipe joints, connections or manhole walls are a few of the common locations where infiltration may occur.*

[4] *INFLOW. The water discharged into a sewer system and service connections from such sources as, but not limited to, roof leaders, cellar, yard and area drains, foundation drains, cooling water discharges, drains from springs and swampy areas, around manhole covers or through holes in the covers, cross connections from storm and combined sewer systems, catch basins, storm waters, surface runoff, street wash waters or drainage.*

[5] *EXFILTRATION (EX-fill-TRAY-shun). Liquid wastes and liquid carried wastes which unintentionally leak out of a sewer pipe system and into the environment.*

when the budget is inadequate for the total need. How often do you see a sign. "Your tax dollar is at work cleaning and repairing your sewer?"

7. The ditches in which sewers are installed have the bottoms sloping downhill to produce gravity flow. Gravel and sand placed in the ditch for pipe bedding and cover create ideal conditions to move water for great distances down the trench. Water that enters this backfilled ditch is not easily percolated (seep) out of the ditch because the usual silt and clay soils have been compacted both on the ditch bottom and sidewalls by the heavy excavation equipment.

   Many of these ditches start at the toe (bottom) of foothill slopes where the natural soil conditions produce springs or lateral water flow into the ditch. This water can cause flow down the ditch and create serious problems along a downstream sewer where no one would expect water in the ditch. Problems that can develop include groundwater infiltration into the sewer, possible flotation of the sewer, or structural failure of the sewer or joint.

8. The Administrator of the Environmental Protection Agency cannot authorize grants for the construction of wastewater treatment plants if the wastewater collection system discharging into a plant is subject to excessive infiltration.[6] Consequently municipalities must reduce infiltration to the extent that is cost effective and properly maintain the wastewater collection system to qualify for federal construction grants. Reducing infiltration/inflow is good practice because it allows the collection system to handle greater quantities of wastewater.

9. Negligence and vandalism can be the source of collection system problems. Vandals may place objects such as rocks and tree branches in manholes. Stick-ball bats have been pushed through the holes in manhole lids. Contractors repaving roads have allowed material to enter manholes. Any material in a sewer will slow the flow and allow other solids to settle.

10. Poor records regarding complaints from the public or the date and location of stoppages that had to be cleared can result in an ineffective maintenance program. Good records, regular analysis of the records, and use of this information can produce a cost effective preventive maintenance program.

The discussion has explained why many wastewater collection systems now present such a mammoth problem to the taxpayer and governmental agencies. Fortunately there exist today properly designed, constructed, operated and maintained collection systems that can serve as examples of how the job should be done. Leakage should not be a problem in properly constructed and maintained sewers.

Operation and maintenance of wastewater collection systems on a trouble or emergency basis has been the usual procedure and policy in many communities and districts. Planned operation and preventive maintenance of the collection system has been delayed or omitted, in spite of desires by collection system operators. Municipal officials tended to neglect collection systems as long as complaints were not excessive. To please constituents, officials often demanded street and sidewalk repair be done by collection system crews, but seldom have they ever demanded preventive work on collection systems.

2.2 WHY HAVE COLLECTION SYSTEMS?

First we should consider why we have wastewater collection systems and then I think we will understand why we should take care of them. Collection systems were built to remove diseases that man comes in contact with when he lives surrounded by other people and their wastes. Roman and other early civilizations built drains and aqueducts to carry away their wastes. Wherever large population centers developed, a means of waste handling and removal was needed. In 1888, Dr. McVail reviewed the Methods and Objectives of Preventive Medicine. Three basic lines of defense were outlined as constituting the preventive measures. They were (1) sanitation (cleanliness), (2) inoculation (vaccination for protection against diseases), and (3) isolation (keeping sick people away from healthy people). Sanitation was considered the most important of the three. Also emphasized was the need for a good environment suitable for humans. If you wish more information, I suggest you read Waring's book on *SEWERAGE AND LAND DRAINAGE*.[7] This was written in 1889, but many of the reasons for collection systems are true today!

SANITATION
INOCULATION

2.3 COMPARISONS OF COLLECTION SYSTEMS

You will find city and county officials that will know the cost of each building and their total building budget. Bridges and parks are obvious and everyone can see neglect, but you will find few city and county officials who know for sure how many feet of sewers they have and the number of manholes in their system. Few cities or agencies have correct maps of their wastewater collection system or of the connections to the system. Officials become aware of sewers mainly when the service is inadquate, a stoppage occurs, the system fails, or odors are produced.

---

[6] *Public Law 92-500, Section 201. "Federal Water Pollution Control Act Amendments of 1972." 92nd Congress, S. 2770, Washington, D.C., October 18, 1972.*

[7] *Waring, George Edwin, SEWERAGE AND LAND DRAINAGE, D. Van Nostrand, New York, New York, 1889.*

We know how many pumping plants are in the collection system, where the wastewater treatment plants we have are located, and the number of people we think it takes to operate and maintain them. Numbers of operators will vary from city to city, but you will find some agreement. Unfortunately officials often forget or neglect adequate inspection during construction, and fail to budget adequately for personnel and equipment requirements for the proper operation and maintenance of collection systems. The following sections contain comparisons of collection systems with highways, traffic signals and railroad crossings.

2.31 Highway and Street Comparison

Drive down a road. If it is too rough or bumpy you can call the highway department and complain. You and every other driver and passenger who have passed over that section of road know how bad it is. You become inspectors for the highway department. The highway patrol and local police will call in any unsafe section they see. Who notices a sewer if it isn't overflowing or stinking?

2.32 Traffic Signal Comparison

When the red lights stay on a few seconds longer, you start to stew, but let it fail altogether and quite often you will spend your quarter to call and report its failure. What is going on underground? Who is looking out for the collection system?

2.33 Railroad Crossing Comparison

What happens when the tracks are too rough and every low slung car hits bottom? Motorists call in and complain. The same thing happens when you have a manhole that is in the roadway and causes a bump, or the manhole cover rattles and keeps someone awake. They're interested in your collection system for the first time. Not quite so; just in the manhole that caused the bump or rattle.

You will find that the underground collection system won't draw much attention from anyone until the flow starts coming out of a manhole or some other low overflow point, such as a basement drain or shower drain in a home.

I think by now you are getting the point. One reason a staff is needed to operate and maintain a collection system is that you don't have all of the outside help to let you know when there is a problem. Most people tend to neglect devices and equipment until there is a serious squeak, rattle, or bump that makes the problem obvious and usually serious.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 20.

2.1A List five problems or reasons why many wastewater collection systems are in need of repair or replacement.

2.2A What is the purpose of wastewater collection systems?

2.3A Why aren't people more concerned about collection systems?

2.4 WHY OPERATION AND MAINTENANCE OF YOUR WASTEWATER COLLECTION SYSTEM?

2.41 What Is Operation and Maintenance?

Let's talk about something all of us understand — our car. You have to drive or operate your car to make it take you someplace. If you drive your car improperly or recklessly, you could have an accident and seriously injure yourself and damage your car. Also you have to consider such things as oil, water, grease, tires, and washing. This is the maintenance of your auto. Don't add or change oil and soon you will be walking. After this happens, anything you do could be a repair that was caused by your lack of maintenance. So operation is driving your car and maintenance is keeping it in good running order so that you can depend upon it when you need it.

Operation and maintenance of your wastewater collection system is not letting wastewater overflow into the street or into someone's home. After it has overflowed you must take emergency action because your operation and maintenance program did not prevent the stoppage.

Don't think the agency you work for is a failure if it has main line stoppages. These will occur in even a well operated and maintained system. You will wonder how the material causing the stoppage got into the line. I have found everything from bikes, tree limbs, blocks of concrete and even V.W. fenders in our sewers and manholes.

2.42 How to Tell When You Need To Do A Better Job

If the stoppage is roots, for example, in the same place each time and your records show it has happened ten times, you should have corrected this problem long ago.

Let's go back to your car that had *NO OIL* and caused you to walk and pay a big repair bill. No way would you let this happen ten times. You would soon find the cause for *NO OIL* and stop it from occurring again.

We need to have the same type of concern when a sewer stoppage occurs, the collection system produces obnoxious odors, or a lift station failure occurs.

2.5 THE COST OF YOUR WASTEWATER COLLECTION SYSTEM

When collection systems are installed, they sometimes cost significantly more than the cost of the wastewater treatment plant. If for some reason, the collection system fails in, let's say, twenty years, the cost per foot for replacement could be as much as ten times its original cost. In some locations the replacement is practically impossible and extremely expensive because of the crowding of other utilities, and the fact that everything is going underground now makes this even more of a problem.

Good collection system inspection, operation and maintenance are by far the best ways to protect a large investment that the taxpayers have placed in your hands. An effective inspection program will alert you to small problems that should be corrected before they become big problems.

2.6 THE WASTEWATER COLLECTION SYSTEM DOCTOR

This manual will cover many ways to help you properly operate and diagnose the ills of wastewater collection systems. Even more important, it will teach you the cure for these ills.

Picture yourself now as a doctor of wastewater collection systems and seeking cures for the ills a collection system could acquire. The manual will equip you with many different ways to solve the same or similar problems. As you become more acquainted with these methods and know how to evaluate each one, you will become a better employee and your feeling of job accomplishment will grow.

You are not always going to diagnose the problem correctly the first time, and may work on a symptom and not the cause of the problem. One way to avoid this is to review your information carefully for gaps and the method you have selected to correct the problem. Keep good records to help you next time. If you don't know about mistakes, you can't learn from them. Experience is trying and learning what works and doesn't work, and then avoiding use of the "didn't work" procedures again for these conditions. Try to learn from the experience of others in your field.

EXAMPLE

If possible and appropriate, TV the section in question. See, before you attempt to diagnose the problem. Go back and re-TV after corrective action to see if your selection of a corrective meaure was effective. If you don't have a TV unit, maintain careful and accurate records of a problem section. Attempt to evaluate corrective action with other methods such as visual inspection mirrors and cleaning devices that can provide data regarding the condition of the section and the effectiveness of the action taken.

2.7 SUMMARY

In this chapter you have learned why it is necessary to operate and maintain wastewater collection systems. We have discussed some of the problems and how or why they occur. This is intended to introduce you to these topics. You will find more detail in later chapters.

You are now ready to go on to Chapter 3 which describes collection systems and deals with design and construction. Many problems actually originate when the collection system is first designed and built. Chapter 2 has told you why collection systems need to be properly operated and maintained. Chapter 3 actually begins the discussions on how to do it.

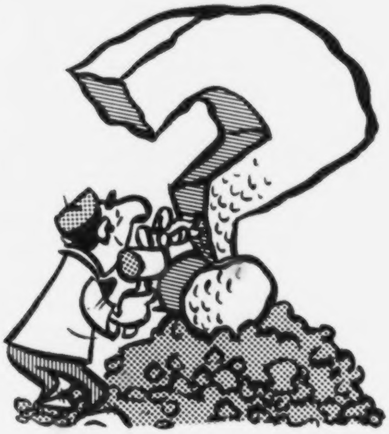
QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 20.

2.4A What is wastewater collection system operation and maintenance?

2.5A How can the taxpayer's investment in your wastewater collection system be protected?

2.6A What should you do after you have selected a method of solving a collection system problem and you think you have corrected the problem?



SUGGESTED ANSWERS

Chapter 2. WHY COLLECTION SYSTEM OPERATION AND MAINTENANCE?

Answers to questions on page 18.

2.1A Many wastewater collection systems are in need of repair or replacement because of

1. Inadequate capacities.
2. Improper construction, inspection and/or low-bid short cuts.
3. Joints that cannot flex and maintain tightness.
4. Insufficient concern for potential damage to pipe joints by plant roots.
5. Lack of preventive maintenance.
6. Priorities among other jobs a collection system maintenance department may have to do such as maintain streets, sidewalks, and the drinking water system.
7. Characteristic of ditches that allows surface or groundwater to flow down ditch.
8. Corrosion of materials due to conditions found in collection systems.
9. Negligence and vandalism.
10. Poor record keeping.

2.2A The purpose of wastewater collection systems is to carry our wastewater away from our homes and industries to the wastewater treatment plant.

2.3A People aren't very concerned about collection systems because they are out of sight and out of mind.

Answers to questions on page 19.

2.4A Operation and maintenance of your wastewater collection system is not letting it overflow into the street or into someone's home. This means keeping the system in such a condition that stoppages rarely occur and when they do, they are quickly relieved.

2.5A Good collection system operation and maintenance is the only protection of the large investment the taxpayers have in the system.

2.6A After a problem has been corrected, the effectiveness of the corrective action should be evaluated and good records should be kept for reference.

OBJECTIVE TEST

Chapter 2. WHY COLLECTON SYSTEM OPERATION AND MAINTENANCE?

Please mark correct answers on answer sheets as directed at the end of Chapter 1. There may be more than one answer to each question.

1. Wastewater collection systems require rehabilitation and upgrading because
   1. Area served by the collection system experienced inadequate growth.
   2. Collection systems were installed as designed.
   3. Flexible joints were installed.
   4. Negligence and vandalism have caused problems.
   5. Vapor-tight joints were installed.
2. Collection systems have not been installed as designed due to problems caused by
   1. Faulty construction.
   2. Inadequate public relations.
   3. Lack of management interest in safety.
   4. Low-bid short cuts.
   5. Poor inspections.

3. Sewer pipes should have flexible joints because of
   1. Earth movements.
   2. Root intrusion.
   3. Settling of structures.
   4. Vibrations of traffic.
   5. No, should be rigid to prevent leaks.

4. Root growth is a principal cause of pipe damage that allows
   1. Exfiltration.
   2. Infiltration.
   3. Inflow.
   4. Preventive maintenance.
   5. Sealing of cracks.

5. Water moving through gravel and sand placed in a ditch for pipe bedding can cause
   1. Groundwater infiltration into sewer.
   2. Flotation of the sewer pipe.
   3. Opportunity for television inspection of sewer.
   4. Structural failure of the sewer joint.
   5. Wash out of soils and street collapse.

6. A cost effective preventive maintenance program can be produced by
   1. Disregarding complaints from public.
   2. Good records.
   3. Ignoring dates and locations of stoppages.
   4. Regular analysis of records.
   5. Use of records.

7. Municipal officials become aware of wastewater collection systems when
   1. Odors are produced.
   2. Service is inadequate.
   3. Stoppages occur.
   4. System fails.
   5. Wastewater flows through system.

8. A staff is needed to operate and maintain a wastewater collection system because
   1. Complaints of malfunctioning street lights must be reported and recorded.
   2. Outside help is not available to detect problems.
   3. People are needed to do the job.
   4. People notify collection system operators only when serious problems occur.
   5. The street department needs to be notified when potholes in the street develop.

9. Operation and maintenance (O & M) of wastewater collection systems is
   1. Allowing stoppages to occur.
   2. Causing manholes to rattle and be noisy.
   3. Keeping wastewater flowing through the pipes.
   4. Preventing lift station failures.
   5. Producing obnoxious odors.

10. Collection system operators are similar to doctors because they
    1. Allow problems to become serious before correcting the problem.
    2. Diagnose collection system problems and prescribe corrective action.
    3. Ignore complaints from the public.
    4. Keep good records and learn what works effectively.
    5. Seek cures for the ills a collection system could acquire.

11. Wastewater collection systems are built to
    1. Carry away potential disease producing material from our homes.
    2. Collect excessive groundwater.
    3. Connect pipes to manholes.
    4. Convey wastewater away from our homes.
    5. Deliver irrigation water to farms.

12. Replacement of wastewater collection systems in some downtown streets is difficult because (select only one answer, the BEST answer)
    1. Of the crowding of other underground utilities.
    2. Records have not been maintained properly and the collection system is lost.
    3. Some people have landscaped their backyards over the collection system and do not want their yard dug up.
    4. The hills are too steep.
    5. The streets have to be paved again.

END OF OBJECTIVE TEST

CHAPTER 3

WASTEWATER COLLECTION SYSTEMS (Purpose, Components and Design)

by

Steve Goodman

NOTICE

This chapter, from page 23 to 68, considers three topics: the purpose, the components and the design of wastewater collection systems.

The *SUPPLEMENT* on construction, inspection and testing is provided for reference purposes, but is not required reading for collection system operators in the field study course.

TABLE OF CONTENTS

Chapter 3. WASTEWATER COLLECTION SYSTEMS
(Purpose, Components and Design)

Page

OBJECTIVES 28

OPERATOR'S PROJECT PRONUNCIATION KEY 29

GLOSSARY 30

3.0 Need to Know 36

3.1 Purpose 36

3.2 Quantities of Wastewater 36

- 3.20 Design Period 37
- 3.21 Design Flows 37
- 3.22 Sample Design Flow Calculation 38
- 3.23 Flow Measurement 39
- 3.24 Flow Variations 41

3.3 Components 42

- 3.30 Gravity Collection System 42
- 3.31 Low Pressure Collection System 44
- 3.32 Vacuum Collection System 44
- 3.33 Appurtenances 44

3.4 Design 52

- 3.40 Layout 52
- 3.41 Field Surveys 52
- 3.42 Slope and Size 57
- 3.43 Velocity and Flow 59
- 3.44 Location and Alignment 60
- 3.45 Depth 60
- 3.46 Pipe Materials 61
  - 3.460 Acrylonitrile Butadiene Sytrene Pipe 61
  - 3.461 Asbestos Cement Pipe 61
  - 3.462 Cast and Ductile Iron Pipe 61
  - 3.463 Corrugated Metal Pipe 61
  - 3.464 Polyvinychloride Pipe 62
  - 3.465 Reinforced and Nonreinforced Concrete Pipe 62
  - 3.466 Reinforced Plastic Mortar and Fiberglass Reinforced Pipe 62

3.467 Vitrified Clay Pipe 62
3.468 Pipe Joints 62
3.47 Manhole Materials 63
3.5 Plan and Profile 63
3.6 Design and Review 63
3.60 Office Study 63
3.61 Field Investigation 63
3.62 Design Items Influencing Maintenance 63
3.63 Communication 65
3.64 Construction, Testing and Inspection 65
SUGGESTED ANSWERS 66
OBJECTIVE TEST 67

SUPPLEMENT - Chapter 3. WASTEWATER COLLECTION SYSTEMS
(Construction, Inspection and Testing)

OBJECTIVES 70
3.7 Construction 71
3.70 Excavation and Shoring 71
3.700 Excavation Equipment 71
Trenching Machines 71
Backhoes 71
Clamshells and Draglines 71
Boring and Tunneling Machines 71
Special Equipment 71
3.701 Location of Utilities 71
3.702 Trench Shoring 72
3.71 Controls 78
3.710 Control Points 78
3.711 Use of Construction Controls 80
String Line 80
Batter Boards 82
Fixed-beam Laser 82
3.72 Sewer Pipe Bedding and Initial Backfill 82
3.720 Effects of Bedding and Initial Backfill on Rigid Pipe 84
3.721 Effects of Bedding and Initial Backfill on Flexible Pipe 85
3.722 Bedding Materials 85
Concrete 85
Granular Material 85
Native Material 85

- 3.723 Bedding Construction 85
- 3.724 Special Pipe Foundations 86
- 3.73 Pipe Laying 86
  - 3.730 Handling of Pipe 86
  - 3.731 Placement of Pipe 86
  - 3.732 Joining of Pipe 86
  - 3.733 Protection of Pipe 86
  - 3.734 Completion of Pipe Bedding 87
- 3.74 Sewer Appurtenances 87
  - 3.740 Construction of Manholes 87
  - 3.741 Construction of Cleanouts 88
- 3.75 Sewer Trench Backfill and Compaction 88
  - 3.750 Backfill Materials 88
    - Native Backfill 88
    - Imported Backfill 88
  - 3.751 Placement of Backfill 89
    - Protection of Pipe 89
    - Completing Backfill 89
    - Removal of Trench Shoring 89
  - 3.752 Compaction of Backfill 89
    - Water Compaction 89
    - Mechanical Compaction 90
    - Measurement of Compaction 91
  - 3.753 Surface Restoration 91
    - In Easements 91
    - In Paved Areas 91

3.8 Sewer Construction Inspection and Testing 92
- 3.80 Need for Inspection and Testing 92
- 3.81 Duties of Inspector 92
- 3.82 Qualifications of Inspector 92
- 3.83 Inspecting and Testing Construction Materials 92
  - 3.830 Sewer Pipe 92
  - 3.831 Appurtenances 93
  - 3.832 Pipe Bedding and Trench Backfill Materials 93
  - 3.833 Portland Cement Concrete 93
- 3.84 Inspecting Construction Procedures 93
  - 3.840 Location of Utilities 93
  - 3.841 Trench Excavation 93
  - 3.842 Pipe Laying 93

3.843 Construction of Appurtenances 94
3.844 Trench Backfilling and Compaction 94
3.845 Surface Restoration and Cleanup 94
3.85 Air Testing 94
3.850 Test Pressure 94
3.851 Volume of Air Required 95
3.852 Air Testing Procedures 96
Manhole-to-Manhole 96
Search for Specific Leaks 99
Building Sewers 100
3.86 Water Testing 101
3.860 Equipment Needed 102
3.861 Water Testing Procedures 102
3.87 Mandrel Test 102
3.88 Final Inspection 103
3.89 Construction Records 104
3.890 Daily Reports 104
3.891 Monthly Reports 104
3.892 Building Sewer Locations 104
3.893 "As-Built" Plans 104
3.9 Additional Reading 108

OBJECTIVES

Chapter 3. WASTEWATER COLLECTION SYSTEMS

After completion of Chapter 3 you should be able to do the following:

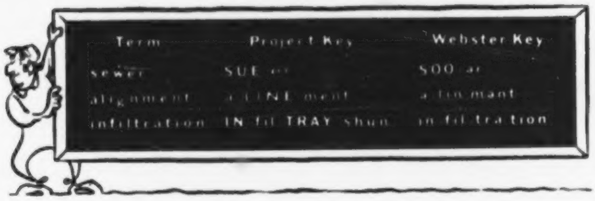
1. List the parts of a wastewater collection system and explain the purpose of each part,
2. Communicate to design engineers the need to consider preventing operation and maintenance problems when designing collection systems,
3. Identify sources and calculate quantities of wastewater flow,
4. Estimate the velocity of water flowing in a sewer, and
5. Review plans and specifications for wastewater collection systems from the viewpoint of effective operation and maintenance of collection systems.

Operator's Project Pronunciation Key

by Warren L. Prentice

The Operator's Project Pronunciation Key is designed to aid you in the pronunciation of new words. While this Key is based primarily on familiar sounds, it does not attempt to follow any particular pronunciation guide. This Key is designed solely to aid operators in this program.

You may find it helpful to refer to other available sources for pronunciation help. Each current standard dictionary contains a guide to its own pronunciation Key. Each Key will be different from each other and from this Key. Examples of the differences between the Key used in this program and the *WEBSTER'S NEW WORLD DICTIONARY KEY*, Second College Edition, 1972[1] are shown below:



Term	Project Key	Webster Key
sewer	SUE er	SOO ar
alignment	a LINE ment	a lin mant
infiltration	IN fil TRAY shun	in fil tra tion

In using this Key, you should accent (say louder) the syllable which appears in capital letters. The following chart is presented to give examples of how to pronounce words using the Operator's Project Key:

	Syllable			
	1st	2nd	3rd	4th
Word				
sewer	SUE	er		
alignment	a	LINE	ment	
infiltration	IN	fill	TRAY	shun

The first word sewer has its first syllable accented. The second word, alignment, has its second syllable accented. The third word, infiltration, has its first and third syllables accented.

We hope you will find the Key useful in unlocking the pronunciation of any new word.

Explanation of Words

The meanings of words in the glossary of this manual are based on current usage by the wastewater collection profession and definitions given in *GLOSSARY — WATER AND WASTEWATER CONTROL ENGINEERING,* prepared by the Joint Editorial Board representing APHA, ASCE, AWWA and WPCF*, 1981. Certain words used by wastewater collection system operators tend to have slightly different meanings in some regions of the United States. We have tried to standardize word meanings as much as possible.

The Appendix, Collection System Words, is a summary of the words in the glossary at the beginning of each chapter.

WORDS
WORDS
WORDS
WORDS

** APHA. American Public Health Association.*
ASCE. American Society of Civil Engineers.
AWWA. American Water Works Association.
WPCF. Water Pollution Control Federation.

---

[1] *The WEBSTER'S NEW WORLD DICTIONARY, Second College Edition, 1972 was chosen rather than an unabridged dictionary because of its availability to most collection system operators.*

GLOSSARY

ALIGNMENT (a-LINE-ment) ALIGNMENT

The proper positioning of parts in a system. The alignment of a pipeline or other line refers to its location and direction.

APPURTENANCE (a-PURR-ten-nans) APPURTENANCE

Machinery, appliances, structures and other parts of the main structure necessary to allow it to operate as intended, but not considered part of the main structure.

BACKWATER GATE BACKWATER GATE

A gate installed at the end of a drain or outlet pipe to prevent the backward flow of water or wastewater. Generally used on storm sewer outlets into streams to prevent backward flow during times of flood or high tide. Also called a TIDE GATE.

BARREL BARREL

(1) The cylindrical part of a pipe that may have a bell on one end.
(2) The cylindrical part of a manhole between the cone and the shelf at the bottom.

BEDDING BEDDING

The prepared base or bottom of a trench or excavation on which a pipe or other underground structure is supported.

BLOCKAGE BLOCKAGE

(1) Partial or complete interruption of flow as a result of some obstruction in a sewer.
(2) When a collection system becomes plugged and the flow backs up, it is said to have a "blockage."
Commonly called a STOPPAGE.

BRANCH SEWER BRANCH SEWER

A sewer that receives wastewater from a relatively small area and discharges into a main sewer serving more than one branch-sewer area.

BUILDING SEWER BUILDING SEWER

A gravity-flow pipeline connecting a building wastewater collection system to a lateral or branch sewer. The building sewer may begin at the outside of the building's foundation wall or some distance (such as 2 to 10 feet) from the wall, depending on local sewer ordinances. Also called a HOUSE CONNECTION or a SERVICE CONNECTION.

CATCH BASIN CATCH BASIN

A chamber or well used with storm or combined sewers as a means of removing grit which might otherwise enter and be deposited in sewers. Also see STORM WATER INLET and CURB INLET.

CAULK (KAWK) CAULK

To stop up and make watertight the joints of a pipe by filling the joints with a waterproof compound or material.

CAULKING (KAWK-ing) CAULKING

(1) A waterproof compound or material used to fill a pipe joint.
(2) The act of using a waterproof compound or material to fill a pipe joint.

CHECK VALVE CHECK VALVE

A special valve with a hinged disc or flap that opens in the direction of normal flow and is forced shut when flows attempt to go in the reverse or opposite direction of normal flows. Also see FLAP GATE and TIDE GATE.

CLEANOUT CLEANOUT

An opening (usually covered or capped) in a wastewater collection system used for inserting tools, rods or snakes while cleaning a pipeline or clearing a stoppage.

COHESIVE (coe-HE-sive) COHESIVE

Tending to stick together.

COMBINED SEWER COMBINED SEWER

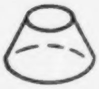
A sewer designed to carry both sanitary wastewaters and storm or surface water runoff.

COMBINED WASTEWATER COMBINED WASTEWATER

A mixture of surface runoff and other wastewater such as domestic or industrial wastewater.

CONCENTRIC MANHOLE CONE CONCENTRIC MANHOLE CONE

Cone tapers uniformly from barrel to manhole cover.



CURB INLET CURB INLET

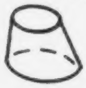
A chamber or well built at the curbline of a street to admit gutter flow to the storm water drainage system. Also see STORM WATER INLET and CATCH BASIN.

DEBRIS (de-BREE) DEBRIS

Any material in wastewater found floating, suspended or moving along the bottom of a sewer. This material may cause stoppages by getting hung up on roots or settling out in a sewer. Debris includes grit, paper, plastic, rubber, silt, and all materials except liquids.

ECCENTRIC MANHOLE CONE ECCENTRIC MANHOLE CONE

Cone tapers nonuniformly from barrel to manhole cover with one side usually being vertical.



EXFILTRATION (EX-fill-TRAY-shun) EXFILTRATION

Liquid wastes and liquid-carried waste which unintentionally leak out of a sewer pipe system and into the environment.

FLAP GATE FLAP GATE

A hinged gate that is mounted at the top of a pipe or channel to allow flow in only one direction. Flow in the wrong direction closes the gate. Also see CHECK VALVE and TIDE GATE.

FLOW LINE FLOW LINE

(1) The top of the wetted line, the water surface or the hydraulic grade line of water flowing in an open channel or partially full conduit.

(2) The lowest point of the channel inside a pipe or manhole. See INVERT. *NOTE:* (2) is an improper definition, although used by some contractors.

FLUSHER BRANCH FLUSHER BRANCH

A line built specifically to allow the introduction of large quantities of water to the collection system so the lines can be "flushed out" with water. Also installed to provide access for equipment to clear stoppages in a sewer.

FORCE MAIN FORCE MAIN

A pipe that carries wastewater under pressure from the discharge side of a pump to a point of gravity flow downstream.

GRIT GRIT

The heavy mineral material present in wastewater such as sand, coffee grounds, eggshells, gravel and cinders. Grit tends to settle out at flow velocities below 2 ft/sec and accumulate in the invert or bottoms of the pipelines.

HYDRAULIC GRADE LINE (H.G.L.) HYDRAULIC GRADE LINE

The surface or profile of water flowing in an open channel or a pipe flowing partially full. If a pipe is under pressure, the hydraulic grade line is at the level water would rise to in a small tube connected to the pipe. To reduce the release of odors from sewers, the water surface or hydraulic grade line should be kept as smooth as possible.

INFILTRATION (IN-fill-TRAY-shun) INFILTRATION

The water entering a sewer system, including service connections, from the ground. Defective pipes, pipe joints, connections or manhole walls are a few of the common locations where infiltration may occur.

INFILTRATION/INFLOW INFILTRATION/INFLOW

The total quantity of water from both infiltration and inflow without distinguishing the source.

INFLOW INFLOW

The water discharged into a sewer system and service connections from such sources as, but not limited to, roof leaders, cellar, yard and area drains, foundation drains, cooling water discharges, drains from springs and swampy areas, around manhole covers or through holes in the covers, cross connections from storm and combined sewer systems, catch basins, storm waters, surface runoff, street wash waters or drainage. See INTERNAL FLOW.

INLET INLET

(1) A surface connection to a drain pipe.
(2) A chamber for collecting storm water with no well below the outlet pipe for collecting grit. Often connected to a CATCH BASIN or a "basin manhole" ("cleanout manhole") with a grit chamber.

INTERCEPTING SEWER INTERCEPTING SEWER

A sewer that receives flow from a number of other large sewers or outlets and conducts the waters to a point for treatment or disposal. Often called an "interceptor."

INTERNAL INFLOW INTERNAL INFLOW

Non-sanitary or industrial wastewaters generated inside of a domestic, commercial or industrial facility and being discharged into the sewer system. Examples are cooling tower waters, basement sump pump discharge waters, continuous-flow drinking fountains, and defective or leaking plumbing fixtures.

INVERT INVERT

The lowest point of the channel inside a pipe or manhole. See FLOW LINE.

INVERTED SIPHON INVERTED SIPHON

A pressure pipeline used to carry wastewater flowing in a gravity collection system under a depression such as a valley or roadway or under a structure such as a building. Also called a "depressed sewer."

LAMP HOLE LAMP HOLE

A small vertical pipe or shaft extending from the surface of the ground to a sewer. A light (or lamp) may be lowered down the pipe for the purpose of inspecting the sewer. Rarely constructed today.

LATERAL SEWER LATERAL SEWER

A sewer that discharges into a branch or other sewer and has no other common sewer tributary to it. Sometimes called a "street sewer" because it collects wastewater from individual homes.

LIFT STATION LIFT STATION

A wastewater pumping station that lifts the wastewater to a higher elevation when continuing the sewer at reasonable slopes would involve excessive depths of trench. Also, an installation of pumps that raise wastewater from areas too low to drain into available sewers. These stations may be equipped with air-operated ejectors or centrifugal pumps. Sometimes called a "pump station," but this term is usually reserved for a similar type of facility that is discharging into a long FORCE MAIN, while a lift station has a discharge line or force main only up to the downstream gravity sewer. Throughout this manual when we refer to lift stations, we intend to include pump stations.

MAIN LINE MAIN LINE

Branch or lateral sewers that collect wastewater from building sewers and service lines.

MAIN SEWER MAIN SEWER

A sewer line that receives wastewater from many tributary branches and sewer lines and serves as an outlet for a large territory or used to feed an intercepting sewer.

MANHOLE MANHOLE

An opening in a sewer provided for the purpose of permitting operators or equipment to enter or leave a sewer. Sometimes called an "access hole."

NOMINAL DIAMETER NOMINAL DIAMETER

Approximate diameter of a pipe; used to describe the size or diameter of a pipe.

NOMOGRAPH (NOME-o-graph) NOMOGRAPH

A graphic representation or means of solving an equation or mathematical relationship. Results are obtained with the aid of a straightedge placed over important known values.

OUTFALL OUTFALL

(1) The point, location or structure where wastewater or drainage discharges from a sewer, drain, or other conduit.
(2) The conduit leading to the final disposal area. See OUTFALL SEWER.

OUTFALL SEWER OUTFALL SEWER

A sewer that receives wastewater from a collection system or from a wastewater treatment plant and carries it to a point of ultimate or final discharge in the environment. See OUTFALL.

OUTLET OUTLET

Downstream opening or discharge end of a pipe, culvert, or canal.

PEAKING FACTOR PEAKING FACTOR

Ratio of a maximum flow to the average flow, such as maximum hourly flow or maximum daily flow to the average daily flow.

PNEUMATIC EJECTOR (new-MAT-tik e-JECK-tor) PNEUMATIC EJECTOR

A device for raising wastewater, sludge or other liquid by compressed air. The liquid is alternately admitted through an inward-swinging check valve into the bottom of an airtight pot. When the pot is filled compressed air is applied to the top of the liquid. The compressed air forces the inlet valve closed and forces the liquid in the pot through an outward swinging check valve, thus emptying the pot.

SANITARY COLLECTION SYSTEM SANITARY COLLECTION SYSTEM

The pipe system for collecting and carrying liquid and liquid-carried wastes from domestic sources to a wastewater treatment plant. Also see WASTEWATER COLLECTION SYSTEM.

SANITARY SEWER SANITARY SEWER

A sewer that carries water and water-carried wastes from residences, commercial buildings, industrial plants, and institutions, together with minor quantities of ground, storm, and surface waters (that are not admitted intentionally) to treatment or disposal facilities.

SEDIMENTATION (SED-uh-men-TAY-shun) SEDIMENTATION

The process of settling and depositing of suspended matter carried by wastewater, by gravity. Sedimentation usually occurs when the velocity of the wastewater is reduced below the point at which it can transport the suspended material.

SEPTIC (SEP-tick) SEPTIC

This condition is produced by anaerobic bacteria. If severe, the wastewater turns black, gives off foul odors, contains little or no dissolved oxygen, and creates a high oxygen demand.

SEWAGE SEWAGE

The used water and water-carried solids from homes that flow in sewers to a treatment plant. The preferred term is WASTEWATER.

SEWER SEWER

A pipe or conduit that carries wastewater or drainage water. The term "collection line" is often used also.

SEWER GAS SEWER GAS

(1) Gas evolved in sewers that results from the decomposition of organic matter in the wastewater. When testing for gases found in sewers, test for lack of oxygen and also for explosive and toxic gases.

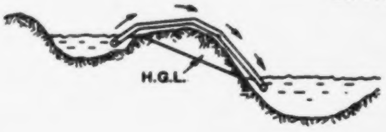
(2) Any gas present in the wastewater collection system, even though it is from such sources as gas mains, gasoline and cleaning fluids.

SEWERAGE SEWERAGE

System of piping with appurtenances for collecting, moving and treating wastewater from source to discharge.

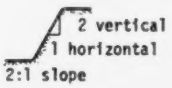
SIPHON SIPHON

A pipe or conduit through which water will flow above the hydraulic grade line (H.G.L.) under certain conditions. Water (or other liquid) is first forced to flow or is sucked through the pipe by creation of a vacuum. As long as no air enters the pipe to interrupt flow, atmospheric pressure on the liquid at the elevated (higher) end of the siphon will cause the flow to continue.



SLOPE SLOPE

The slope or inclination of a sewer or trench excavation is the ratio of the vertical distance to the horizontal distance or "rise over run."



SNAKE SNAKE

A stiff but flexible cable that is inserted into sewers to clear stoppages.

SPRINGLINE SPRINGLINE

Theoretical center of a pipeline; or, the guideline for laying a course of bricks.

STOPPAGE STOPPAGE

(1) Partial or complete interruption of flow as a result of some obstruction in a sewer.
(2) When a sewer system or sewer becomes plugged and the flow backs up, it is said to have a "stoppage." Also see BLOCKAGE.

STORM RUNOFF STORM RUNOFF

The amount of runoff that reaches the point of measurement within a relatively short period of time after the occurrence of a storm or other form of precipitation. Also called "direct runoff."

STORM SEWER STORM SEWER

A sewer that carries storm water and surface water, street wash and other wash waters, or drainage, but excludes domestic wastewater and industrial wastes. Also called "storm drain."

STORM WATER STORM WATER

The excess water running off from the surface of a drainage area during and immediately after a period of rain. See STORM RUNOFF.

STORM WATER INLET STORM WATER INLET

A device that admits surface waters to the storm water drainage system. Also see CURB INLET and CATCH BASIN.

SURFACE RUNOFF SURFACE RUNOFF

(1) The precipitation that is unable to be absorbed by the soil and flows across the surface by gravity.
(2) The water that reaches a stream by traveling over the soil surface or falls directly into the stream channels, including not only the large permanent streams but also the tiny rills and rivulets.
(3) Water that remains after infiltration, interception, and surface storage have been deducted from total precipitation.

TAP TAP

A small hole in a sewer where a wastewater service line from a building is connected (tapped) into a lateral or branch sewer.

TIDE GATE TIDE GATE

A gate with a flap suspended from a free-swinging horizontal hinge, usually placed at the end of a conduit discharging into a body of water having a fluctuating surface elevation. The gate is usually closed because of outside water pressure, but will open when the water head inside the pipe is great enough to overcome the outside pressure, the weight of the flap, and the friction of the hinge. Also called a BACKWATER GATE. Also see CHECK VALVE and FLAP GATE.

TOPOGRAPHY (toe-POG-gra-fee) TOPOGRAPHY

The description or features of an area, such as the hills, valleys, mountains and slope of the land surfaces.

TRUNK SEWER TRUNK SEWER

A sewer that receives many tributary branches and serves a large territory. See MAIN SEWER.

TRUNK SYSTEM TRUNK SYSTEM

A system of major sewers serving as transporting lines and not as local or lateral sewers.

U-TUBE U-TUBE

(1) A pipe shaped like a U that is constructed in a force main to raise the dissolved oxygen concentration in the wastewater.
(2) U-tube manometers are used to indicate the pressure of a gas or liquid in a confined space.

WASTEWATER WASTEWATER

The used water and water-carried solids from a community that flow to a treatment plant. Storm water, surface water, and groundwater infiltration also must be included in the wastewater that enters a plant. The term "sewage" usually refers to household wastes, but this word is being replaced by the term "wastewater."

WASTEWATER COLLECTION SYSTEM WASTEWATER COLLECTION SYSTEM

The pipe system for collecting and carrying water and water-carried wastes from domestic and industrial sources to a wastewater treatment plant.

WASTEWATER FACILITIES WASTEWATER FACILITIES

The pipes, conduits, structures, equipment, and processes required to collect, transport, and treat domestic and industrial wastes, and dispose of the effluent.

WASTEWATER TREATMENT PLANT WASTEWATER TREATMENT PLANT

(1) An arrangement of pipes, equipment, devices, tanks and structures for treating wastewater, industrial wastes, and sludge. (2) A water pollution control plant.

WEIR (weer) WEIR

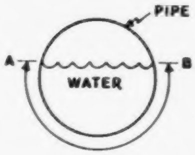
(1) A wall or plate placed in an open channel and used to measure the flow. The depth of flow over the weir can be used to calculate the flow rate, or a chart or conversion table may be used. (2) A wall or obstruction used to control flow (from clarifiers) to assure uniform flow and avoid short-circuiting.

WELL POINT WELL POINT

A hollow, pointed rod with a perforated (containing many small holes) tip. A well point is driven into an excavation where water seeps into the tip and is pumped out of the area. Used to lower the water table and reduce flooding during an excavation.

WETTED PERIMETER WETTED PERIMETER

The length of the wetted portion of a pipe covered by flowing wastewater.



Wetted Perimeter = Distance from A to B.

CHAPTER 3. WASTEWATER COLLECTION SYSTEMS

3.0 NEED TO KNOW

Persons responsible for the operation and maintenance of wastewater collection systems usually are not the ones responsible for the design, construction and inspection[1] of these systems. However, a basic knowledge of the components of collection systems, their purpose, and how engineers design the systems will help you do a better job. At the same time, such knowledge will enable you to discuss design, construction and inspection with engineers.

Collection system operators who know how and why wastewater collection systems work, should and will be consulted by design engineers for the purpose of improving the design and construction of future systems.

Understanding the design and construction of the system you will be responsible for operating and maintaining also will assist you in determining the correct action to take when the system fails to operate properly. In some emergency situations you may be called upon to design and to construct a small, temporary portion of the wastewater system you are maintaining.

3.1 PURPOSE

The purpose of a wastewater collection system is to collect and convey the wastewater from a community's homes and industries. The water carries the wastes in the form of either dissolved or suspended solids. Wastewater collection systems must be properly designed and constructed to provide a water velocity of around 2.5 feet per second. Velocities which are too high or too low can be detrimental to the operation and maintenance of a collection system. The collection system conveys the wastewater and solids to a treatment plant where the pollutants are removed before the treated wastewater is discharged to a body of water or onto land.

The wastewater in collection systems is usually conveyed by gravity utilizing the natural slope of the land. Wastewater pumps are used when the slope of the land requires lifting the wastewater to a higher elevation for a return to gravity flow. Pumps and other mechanical equipment require extensive maintenance and costly energy to operate so their use is avoided whenever possible. Thus the location and design of the components of a collection system are strongly influenced by the topography (surface contour) of its service area. In some instances, where the topography is unfavorable for a gravity collection system, a pressure or vacuum collection system may be used.

Collection system operators need to recognize the differences between the sanitary wastewater collection systems described above, a similar storm water system, and a combined storm and wastewater collection system. A storm water collection system conveys water resulting from runoff of rainfall and snow melt from buildings and surrounding unpaved and paved areas to a natural watercourse or body of water, usually without treatment. This system also conveys excess water supplied to urban areas for irrigation and surface cleaning. A combined wastewater and storm water collection system conveys a combination of these waters to a treatment plant. Occasionally an excessively heavy rain or cloud burst may produce flows which exceed the wastewater treatment plant's capacity. The excess flow may be diverted to specially designed holding tanks or lagoons for storage until the high flows recede. The stored water is then returned to the plant for proper treatment. In a few older communities with combined wastewater collection systems, provisions are usually made to relieve the collection system and treatment plant by diverting the excess flow and providing partial treatment plus disinfection before discharging the flow to water or onto land.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 66.

3.0A Why should a collection system operator understand how the system was designed and constructed?

3.1A What is the purpose of a wastewater collection system?

3.1B In areas where the topography is unfavorable for a gravity wastewater collection system, what types of collection systems may be used?

3.2 QUANTITY OF WASTEWATER

The amount of wastewater that a collection system will convey is determined by careful analysis of the present and probable future quantities of domestic, commercial and industrial wastewaters, as well as anticipated groundwater *INFILTRATION*[2] and surface water *INFLOWS*[3] produced in the service area. The sanitary sewers that make up a collection system are usually designed to convey the peak flow from all of these sources.

---

[1] *Collection system operators in small agencies are sometimes required to inspect sewer construction.*

[2] *Infiltration (IN-fill-TRAY-shun). The water entering a sewer system, including service connections, from the ground. Defective pipes, pipe joints, connections or manhole walls are a few of the common locations where infiltration may occur.*

[3] *Inflow. The water discharged into a sewer system and service connections from such sources as, but not limited to, roof leaders, cellar, yard and area drains, cooling water discharges, drains from springs and swampy areas, around manhole covers or through holes in the covers, cross connections from storm and combined sewer systems, catch basins, storm waters, surface runoff, street wash waters or drainage.*

3.20 Design Period

Ideally a wastewater collection system should be designed to convey the estimated peak flow from its service area when the area has reached its maximum population and has been fully developed commercially and industrially. However, it is not always economically feasible to construct some of the major sewers in a system large enough to convey the ultimate peak flow from its service area. Under these circumstances the sewers are designed to convey peak flows that are estimated to occur within an appropriate design period, generally ranging from 10 to 30 years. Provisions should be made when planning a collection system to provide for expansion of the system before the actual flows become greater than the design flows.

3.21 Design Flows

Once the design period has been determined, design flows that will occur during the period are calculated based on the estimated population, per capita wastewater discharge and industrial and commercial wastewater discharges that will occur at the end of the period. The information in this section and Section 3.22 is provided to show you how a design engineer calculates needed flow capacities. It will also be useful to you, as the system operator, in predicting and managing the increasing flows that accompany commercial and residential development in your service area.

Population estimates can sometimes be obtained from a planning agency that has data covering the collection system's service area. If such information is not available, population estimates are made by using the most appropriate method.[4]

Suitable methods for making the estimates include an arithmetic increase per year, uniform percentage growth rate based on recent census periods, graphical comparison with the growth of other similar but larger cities, and graphical extension of past growth.

Domestic wastewater flow is calculated by multiplying the estimated population in the collection system service area by the per capita flow factors. Typical per capita flows from residential sources range from 70 to 100 gallons per day per person. Wastewater flows from commercial and industrial areas are usually estimated in terms of gallons per day per acre, based on the type of development and measured flows from similar existing developments. Estimation of flows from a proposed unsewered industrial area can be very difficult. Industrial discharges vary widely due to the types of manufacturing processes used by the industries. Information from local zoning commissions regarding the types and sizes of industries expected and permitted to use the area can be very helpful. Typical sewer capacity allowances for commercial and industrial areas are outlined in Table 3.1 (next page).

Some infiltration of groundwater and inflow of surface water occurs in all wastewater collection systems and capacity must be provided for this additional flow. The amount of infiltration entering through cracks in pipes, joints and manholes will vary with age and condition of the collection system and the portion of the system that is submerged in groundwater. The amount of inflow will vary with the number of manholes in a collection system that become submerged in surface water and the number of surface water drainage sources, such as roof drains, that are illegally connected to the collection system. Inflow can be reduced by sealing manhole covers that are subject to flooding during the winter months. Table 3.2 outlines the infiltration design allowance for several cities. Design allowances for infiltration normally include allowances for inflow. Combined collection systems are designed similar to sanitary collection systems with the addition of storm water flows.

The flow of wastewater in a collection system (exclusive of infiltration and inflow) will vary during a 24-hour period with the minimum flow occurring during the early morning and the maximum occurring around noontime. Table 3.3 lists the ratio ranges of maximum and minimum flows to average daily wastewater flow recommended for use in design by various authorities. The ratios in Table 3.3 are often called *PEAKING FACTORS.*[5]

TABLE 3.2 INFILTRATION DESIGN ALLOWANCE FOR SEVERAL CITIES[a]

City (1)	Allowance (gpd/acre)[b] (2)	Remarks (3)
Seattle, WA	1,100	
Bay City, TX	1,000	
Lorain, OH	1,000	
Marion, OH	750	Calculations based on a proposed density, with a 100 gpd/cap average flow and peak of 400 gpd/cap also often used.
Ottumwa, IA	600	Infiltration and exfiltration shall not exceed 200 gal per inch of pipe diameter per mile of pipe per 24 hr period.[c]
West Springfield, MA	2,000	
Alma, MI	140	

[a] *GRAVITY SANITARY SEWER DESIGN AND CONSTRUCTION, Water Pollution Control Federation, Alexandria, Virginia.*

[b] *Higher allowances are used in areas where the cities have high groundwater tables and the sewer lines may be submerged for a portion of the year.*

[c] *Typical construction specification for the acceptance test for a new sewer line.*

---

[4] Refer to GRAVITY SANITARY SEWER DESIGN AND CONSTRUCTION, pages 23 and 24, Water Pollution Control Federation, 601 Wythe Street, Alexandria, VA 22314-1994. Price $19.00 members, $25 nonmembers.

[5] *Peaking Factor. Ratio of a maximum flow to the average flow, such as maximum hourly flow or maximum daily flow to the average daily flow.*

TABLE 3.1 SEWER CAPACITY ALLOWANCES FOR COMMERCIAL AND INDUSTRIAL AREAS[a]

CITY (1)	YEAR DATA PUBLISHED OR OBTAINED (2)	COMMERCIAL ALLOWANCES (GPD/ACRE) (3)	INDUSTRIAL ALLOWANCE (GPD/ACRE) (4)
Cincinnati, OH	1980	Case by case determination after consultation with the Directors of Sewers.	
Dallas, TX	1960	30,000 added to domestic rate for downtown; 60,000 for tunnel relief sewers.	
Grand Rapids, MI	1980	Offices, 40-50 gpd/cap; hotels, 400-500 gpd/room; hospitals, 200 gpd/bed; schools, 200-300 gpd/room.	
Hagerstown, MD	----	Hotels, 180-250 gpd/room; hospitals, 150 gpd/bed; schools, 120-150 gpd/room.	
Houston, TX	1960	Peak flows; Offices 0.36 gpd/sq ft; retail 0-20 gpd/sq ft; hotels 0.93 gpd/sq ft.	
Las Vegas, NV	----	Resort hotels, 310-525 gpd/room; schools, 15 gpd/cap.	
Los Angeles, CA	1980	Commercial, 100 gpd/1,000 sq ft gross floor area; hospitals, 500 gpd/bed (surgical), 85 gpd/bed (convalescent); schools, elementary or jr. high schools — 10 gpd/student; high schools — 15 gpd/student; universities, 20 gpd/student. The above values give peak flow rates. Divide by 3.0 to obtain average flow rates.	15,500
Los Angeles Co. San. District, CA	1980	4,000 - 6,000	
Lincoln, NB	1962	7,000	
Milwaukee, WI	1980	240,000 (max); 25,800 (min).	
St. Joseph, MO	1962	64,000 (downtown) 25,800 (neighborhood)	
St. Louis, MO	1960	90,000 average, 165,000 peak	
Santa Monica, CA	1980	Commercial, 9,700; hotels, 7,750	13,600
Toronto, Ont., CANADA	1980	Analysis of actual water consumption in the commercial and industrial downtown area is approximately 20,000 gpd/acre	

---

[a] *GRAVITY SANITARY SEWER DESIGN AND CONSTRUCTION, Water Pollution Control Federation, Alexandria, Virginia.*

TABLE 3.3 DESIGN RATIOS OF MAXIMUM AND MINIMUM TO AVERAGE DAILY FLOW[a]

Population, in thousands	Ratio Ranges[b] Minimum	Maximum
1	0.20	3.9 - 5.5
5	0.26 - 0.27	3.3 - 4.5
10	0.29 - 0.32	2.9 - 4.0
50	0.39 - 0.44	2.3 - 2.9
100	0.43 - 0.50	2.0 - 2.6
200	0.48 - 0.57	1.8 - 2.3
500	0.55 - 0.69	1.5 - 1.9

[a] *Adapted from GRAVITY SANITARY SEWER DESIGN AND CONSTRUCTION, Water Pollution Control Federation, Alexandria, Virginia.*

[b] *NOTE: As the population increases the ratio ranges become closer to one, thus there is less fluctuation in flows.*

3.22 Sample Design Flow Calculation

EXAMPLE 1

The estimated design flow for a typical wastewater collection system can be calculated given the following information on the system's service area and the assumed flow data.

Given Information:

Service area	10,000 acres
Present population	30,000 people
Estimated design period population	50,000 people
Estimated commercial area	500 acres
Estimated industrial area	700 acres

Assumed Flow Data:

Per capita flow	85 gallons per day per person (GPCD)
Commercial flow allowance	5,000 GPD/acre
Industrial flow allowance	13,000 GPD/acre
Infiltration flow allowance	600 GPD/acre

Design Flow:

Residential flow,

$$\frac{(50{,}000\text{ people})(85\text{ GPD/capita})}{1{,}000{,}000/\text{M}^{**}} = \underline{\underline{4.25\text{ MGD}^{*}}}$$

Peak residential flow,

$$4.25 \text{ MGD} \times 2.6 \text{ peaking factor} = 11.05 \text{ MGD}$$

Commercial capacity allowance,

$$\frac{(500 \text{ acres})(5{,}000 \text{ GPD/acre})}{1{,}000{,}000/\text{M}} = 2.50 \text{ MGD}$$

Industrial capacity allowance,

$$\frac{(700 \text{ acres})(13{,}000 \text{ GPD/acre})}{1{,}000{,}000/\text{M}} = 9.10 \text{ MGD}$$

Infiltration and inflow capacity allowance,

$$\frac{(10{,}000 \text{ acres})(600 \text{ GPD/acre})}{1{,}000{,}000/\text{M}} = 6.00 \text{ MGD}$$

Total design flow = 28.65 MGD

(11.05 + 2.50 + 9.10 + 6.00)

3.23 Flow Measurement

Collection system operators will need to know the fundamentals of wastewater flow measurement in a sewer pipe. There are many devices available for flow measurement. All of these flow meters are based on the simple principle that the flow rate equals the velocity of flow multiplied by the cross-sectional area of the flow. This principle is expressed by the following formula:

$$Q, \text{ cubic feet per second} = (\text{Area, sq ft})(\text{Velocity, ft/sec})$$

Calculation of the cross-sectional area of flow in a sewer line can be made by using a factor found in Table 3.4. This procedure is explained in EXAMPLE 2.

EXAMPLE 2

The depth of flow in a 12-inch diameter sewer is 5 inches. Determine the cross-sectional area of the flow.

KNOWN	UNKNOWN
D or Diameter, in = 12 in	Cross-sectional area, sq ft
d or Depth, in = 5 in	

To determine the cross-sectional area for a sewer pipe flowing partially full use the following steps:

1. Find the value for the depth, d, divided by the diameter, D.

$$\frac{d, \text{ in}}{D, \text{in}} = \frac{5 \text{ in}}{12 \text{ in}}$$
$$= 0.42$$

2. Find the correct factor for 0.42 in Table 3.4.

$$\frac{d}{D} = 0.42 \qquad \text{Factor} = 0.3130$$

3. Calculate the cross-sectional area.

$$\text{Pipe cross-sectional area, sq ft} = \frac{(\text{Factor})(\text{Diameter, in})^2}{144 \text{ sq in/sq ft}}$$
$$= \frac{(0.3130)(12 \text{ in})^2}{144 \text{ sq in/sq ft}}$$
$$= 0.313 \text{ sq ft}$$

Velocities in sewers should be measured in the field to be sure *ACTUAL* velocities are high enough to prevent the deposition of solids. If roots or other obstructions get into a sewer, design velocities can be reduced and problems develop. Actual velocities in sewers can be measured by using dyes or floats. Realize that velocities vary during the day depending on the activities of the tributary population. A scouring velocity should be reached or exceeded during peak flows, but probably will not be reached during low flow periods. Actual velocities should be measured in the field, rather than estimating the velocities by the use of hydraulic formulas which give the theoretical velocity.

DYES. Tracer dyes are very effective for estimating velocities. Put into the upstream manhole the smallest amount of dye that can be seen easily in the downstream manhole. Fluorescent tracer dyes can be obtained from chemical suppliers. The supplier of chemicals for a wastewater treatment plant is a good source to recommend the proper type of dye. The amount of dye used will depend on the type of dye, diameter of sewer and estimated flow in the sewer.

After the dye has been inserted in the flow at the upstream manhole, measure and record two readings:

1. Total travel time from insertion of dye until the dye is first seen at the downstream manhole (t_1); and
2. Total travel time from insertion of dye until the dye is no longer visible at the downstream manhole (t_2).

The average travel time is $(1/2)(t_1 + t_2)$. The average velocity is calculated by dividing the distance (between manholes) by the average time.

$$\text{Velocity, ft/sec} = \frac{\text{Distance, ft}}{\text{Average Time, sec}}$$

FLOATS. Floats are used to estimate velocities in existing sewers flowing partially full. A float could be a stick, an orange, or any other object that can be easily identified and that travels down the sewer at a velocity similar to the wastewater. Velocity is determined by recording the time the float takes to travel a known distance, such as the distance between manholes. Most surface floats such as sticks or oranges travel from 10 to 15 percent faster than the average velocity due to the velocity differences between the surface and bottom sections of the flowing water. Float travel down a sewer line may be hindered by obstructions in the line such as protruding taps, roots, grease deposits or the crown (top) of the pipe. If the float travel time is slower than normal, try double checking the time using a dye.

---

* MGD. Million Gallons per Day.

** 1,000,000/M. This means 1,000,000/Million which is similar to saying 12 in/ft.

TABLE 3.4 AREA OF PARTLY FILLED CIRCULAR PIPES

d/D	Factor	d/D	Factor
0.01	0.0013	0.51	0.4027
0.02	0.0037	0.52	0.4127
0.03	0.0069	0.53	0.4227
0.04	0.0105	0.54	0.4327
0.05	0.0174	0.55	0.4426
0.06	0.0192	0.56	0.4526
0.07	0.0242	0.57	0.4625
0.08	0.0294	0.58	0.4724
0.09	0.0350	0.59	0.4822
0.10	0.0409	0.60	0.4920
0.11	0.0470	0.61	0.5018
0.12	0.0534	0.62	0.5115
0.13	0.0600	0.63	0.5212
0.14	0.0668	0.64	0.5308
0.15	0.0739	0.65	0.5404
0.16	0.0811	0.66	0.5499
0.17	0.0885	0.67	0.5594
0.18	0.0961	0.68	0.5687
0.19	0.1039	0.69	0.5780
0.20	0.1118	0.70	0.5872
0.21	0.1199	0.71	0.5964
0.22	0.1281	0.72	0.6054
0.23	0.1365	0.73	0.6143
0.24	0.1449	0.74	0.6231
0.25	0.1535	0.75	0.6319
0.26	0.1623	0.76	0.6405
0.27	0.1711	0.77	0.6489
0.28	0.1800	0.78	0.6573
0.29	0.1890	0.79	0.6655
0.30	0.1982	0.80	0.6736
0.31	0.2074	0.81	0.6815
0.32	0.2167	0.82	0.6893
0.33	0.2260	0.83	0.6969
0.34	0.2355	0.84	0.7043
0.35	0.2450	0.85	0.7115
0.36	0.2545	0.86	0.7186
0.37	0.2642	0.87	0.7254
0.38	0.2739	0.88	0.7320
0.39	0.2836	0.89	0.7384
0.40	0.2934	0.90	0.7445
0.41	0.3032	0.91	0.7504
0.42	0.3130	0.92	0.7560
0.43	0.3229	0.93	0.7612
0.44	0.3328	0.94	0.7662
0.45	0.3428	0.95	0.7707
0.46	0.3527	0.96	0.7749
0.47	0.3627	0.97	0.7785
0.48	0.3727	0.98	0.7816
0.49	0.3827	0.99	0.7841
0.50	0.3927	1.00	0.7854

EXAMPLE 3

A stick travels the 400 feet between two manholes in three minutes and 20 seconds (200 seconds). Estimate the velocity in the sewer.

KNOWN	UNKNOWN
Distance, ft = 400 ft	Velocity, ft/sec
Time, sec = 200 sec	

$$\text{Velocity, ft/sec} = \frac{\text{Distance, ft}}{\text{Time, sec}}$$

$$= \frac{400\text{ ft}}{200\text{ sec}}$$

$$= 2\text{ ft/sec}$$

NOTE: The velocity of the stick (2 ft/sec) is 10 to 15 percent faster than the average velocity of the wastewater in the sewer.

$$\begin{aligned}\text{Average Velocity, ft/sec} &= 2\text{ ft/sec} - 2\text{ ft/sec}(0.10\text{ to }0.15)\\ &= 2\text{ ft/sec} - 0.2\text{ to }0.3\text{ ft/sec}\\ &= 1.7\text{ to }1.8\text{ ft/sec}\end{aligned}$$

Assuming the channel in the manhole at the downstream end of the section of sewer line in which the velocity was determined is similar in cross section to the sewer line, the cross section of the area of flow can be determined by measuring the depth of flow at the manhole.

Knowing the velocity and cross-sectional area of the flow in a sewer line, the quantity of flow or flow rate can then be calculated.

EXAMPLE 4

The velocity in a 12-inch sewer line is 1.7 ft/sec and the flow cross-sectional area is 0.3132 sq ft. Determine the rate of flow.

KNOWN	UNKNOWN
Velocity, ft/sec = 1.7 ft/sec	Flow, cu ft/sec
Area, sq ft = 0.3132 sq ft	

Calculate the rate of flow in cubic feet per second.

$$\begin{aligned}\text{Flow, cu ft/sec} &= (\text{Velocity, ft/sec})(\text{Area, sq ft})\\ &= (1.7\text{ ft/sec})(0.3132\text{ sq ft})\\ &= 0.53\text{ cu ft/sec}\end{aligned}$$

This calculation produces the flow rate in the sewer line in cubic feet per second. However, flow rates of wastewater are generally expressed in million gallons per day rather than cubic feet per second. Example 5 illustrates the method of converting cubic feet per second (CFS) to million gallons per day (MGD).

EXAMPLE 5

Convert a flow of 0.53 cubic feet per second to million gallons per day.

KNOWN	UNKNOWN
Flow, CFS = 0.53 CFS	Flow, MGD
1 cu ft = 7.48 gal	
1 day = 86,400 sec	

1. Develop a conversion factor for CFS to MGD. This conversion factor is very useful.

$$1\text{ MGD} = \frac{(1\text{ M Gal/day})(1{,}000{,}000/\text{M})}{(7.48\text{ gal/cu ft})(86{,}400\text{ sec/day})}$$

$$= 1.55\text{ cu ft/sec}$$

$$= 1.55\text{ CFS}$$

$$\text{or }1\text{ CFS} = \frac{1\text{ CFS}}{1.55\text{ CFS/MGD}}$$

$$= 0.646\text{ MGD}$$

2. Calculate the flow in million gallons per day using the known flow in cubic feet per second.

$$\text{Flow, MGD} = \frac{(\text{Flow, CFS})}{(1.55\text{ CFS/MGD})}$$

$$= \frac{0.53\text{ CFS}}{1.55\text{ CFS/MGD}}$$

$$= 0.34\text{ MGD}$$

3.24 Flow Variations

Knowledge of the daily and annual variations or fluctuations in a collection system's wastewater flow is useful in planning maintenance programs for the system. For example, collection system hydraulic cleaning operations using the flow in the system should be scheduled during the hours of sufficient flows. On the other hand, cleaning with bucket equipment should be scheduled during the hours of minimum flow in the system. Of course, upstream diversion of flow, if possible, should always be considered as a means of developing an optimum maintenance schedule.

Figure 3.1 illustrates daily fluctuations of dry weather wastewater flow from a typical residential community. An industry with a significant wastewater discharge would impose a different flow fluctuation on a collection system depending on its pattern of wastewater discharge. This can be determined by flow measurement. You could then construct a combined fluctuation chart, similar to Figure 3.1, for the flows from your combined residential and industrial sources, or the fluctuation in total flows could be measured in the collection system downstream of the point of combined flows.

To construct a chart showing your system's annual flow fluctuations, calculate the typical monthly residential flows. Add to these amounts any industrial flows including known or estimated fluctuations. Next, add in your estimates of infiltration and inflow amounts, on a monthly basis. Infiltration and inflow[6] will vary proportionally to the seasonal variation in groundwater levels and rainfall intensity. Graph the monthly amounts as you did for daily totals. The resulting chart can be used to help you plan long-term periodic maintenance activities. High levels of infiltration and inflow can be reduced, especially in older collection systems, by an effective sewer rehabilitation program (Chapter 10).

---

[6] *Infiltration and inflow may also be referred to as I & I or I/I.*

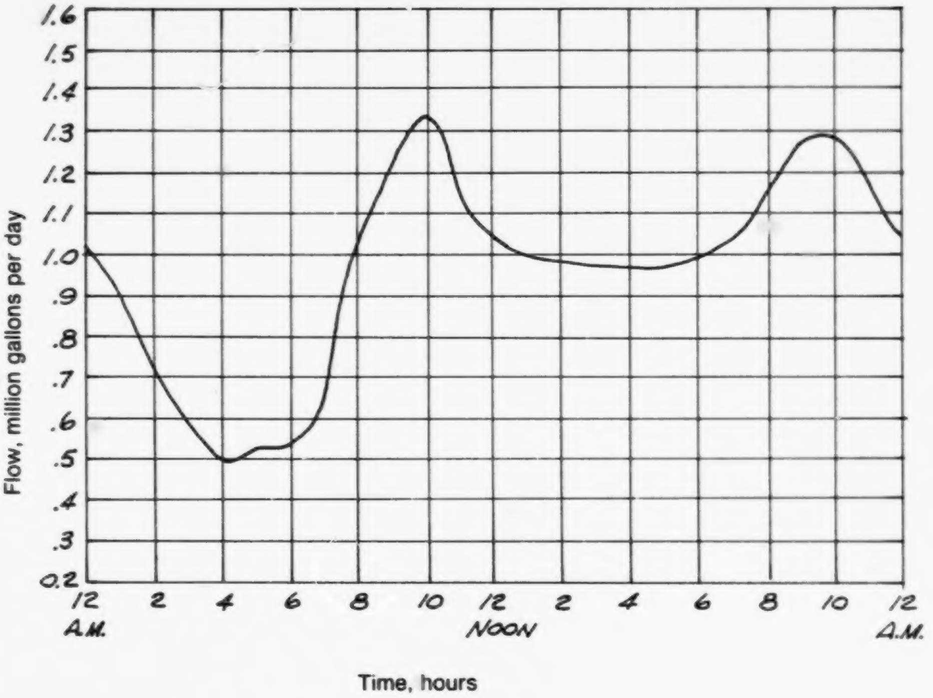


Fig. 3.1 Variations of dry weather wastewater flow from a typical community

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 66.

3.2A List the sources or types of wastewater conveyed by wastewater collection systems.

3.2B What factors are considered in estimating peak flow from an area?

3.2C What measurement aids are commonly used to measure actual flow velocity in sewer mains?

3.3 COMPONENTS

Let's take a wastewater collection system apart and identify the parts and their purposes. In doing this we will start at the upper end (highest point) and follow the flow path of wastewater through the system.

3.30 Gravity Collection System

Wastewater from residences, commercial and industrial developments is collected and conveyed to wastewater treatment plants through the following parts of a gravity wastewater collection system:

BUILDING SEWERS. A building sewer connects a building's internal wastewater drainage system (plumbing) to the larger street sewer. Technically, a building sewer may connect with a lateral sewer, a main sewer, or a trunk sewer, depending on the layout of the system. (All of these sewers are parts of the sewer in the street.) The building sewer may begin immediately at the outside of a building or some distance (such as 2 to 10 feet) from the foundation, depending on local building codes. Where the sewer officially begins marks where the building plumber's responsibility ends and the collection system operator's responsibility starts for maintenance and repair of the system. Figure 3.2 illustrates a typical building sewer and *APPURTENANCES*.[7]

LATERAL AND BRANCH SEWERS are the upper ends of the street sewer components of a collection system. In some instances lateral and branch sewers may be located in easements. This location should be avoided where possible due to maintenance problems created by locations with difficult access and limited work space. Figure 3.3 illustrates the typical location of lateral and branch sewers.

MAIN SEWERS collect the wastewater of several lateral and branch sewers from an area of several hundred acres and convey it (the wastewater) to larger trunk sewers. Figure 3.3 illustrates the typical location of main sewers in a collection system.

TRUNK SEWERS are the main "arteries" of a wastewater collection system and convey the wastewater from numerous main sewers either to a treatment plant or an interceptor sewer. Figure 3.3 illustrates the location of trunk sewers in a typical collection system.

INTERCEPTING SEWERS receive the wastewater from trunk sewers and convey it to the treatment plant. Some of the trunk sewers may have previously discharged directly into bodies of water or may have routed wastewater to now-abandoned treatment plants. The location of intercepting sewers in a typical collection system is illustrated in Figure 3.3.

---

[7] *Appurtences (a-PURR-ten-nans-ses). Machinery, appliances, structures and other parts of the main structure necessary to allow it to operate as intended, but not considered part of the main structure.*

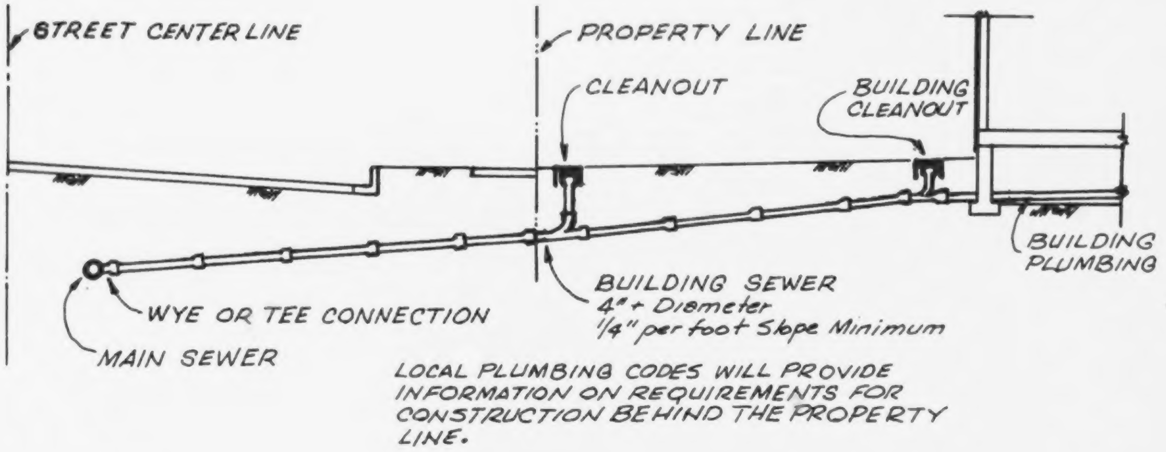

STREET CENTER LINE
PROPERTY LINE
CLEANOUT
BUILDING CLEANOUT
BUILDING PLUMBING
BUILDING SEWER
4" + Diameter
1/4" per foot Slope Minimum
WYE OR TEE CONNECTION
MAIN SEWER
LOCAL PLUMBING CODES WILL PROVIDE INFORMATION ON REQUIREMENTS FOR CONSTRUCTION BEHIND THE PROPERTY LINE.

Fig. 3.2 Typical Building Sewer

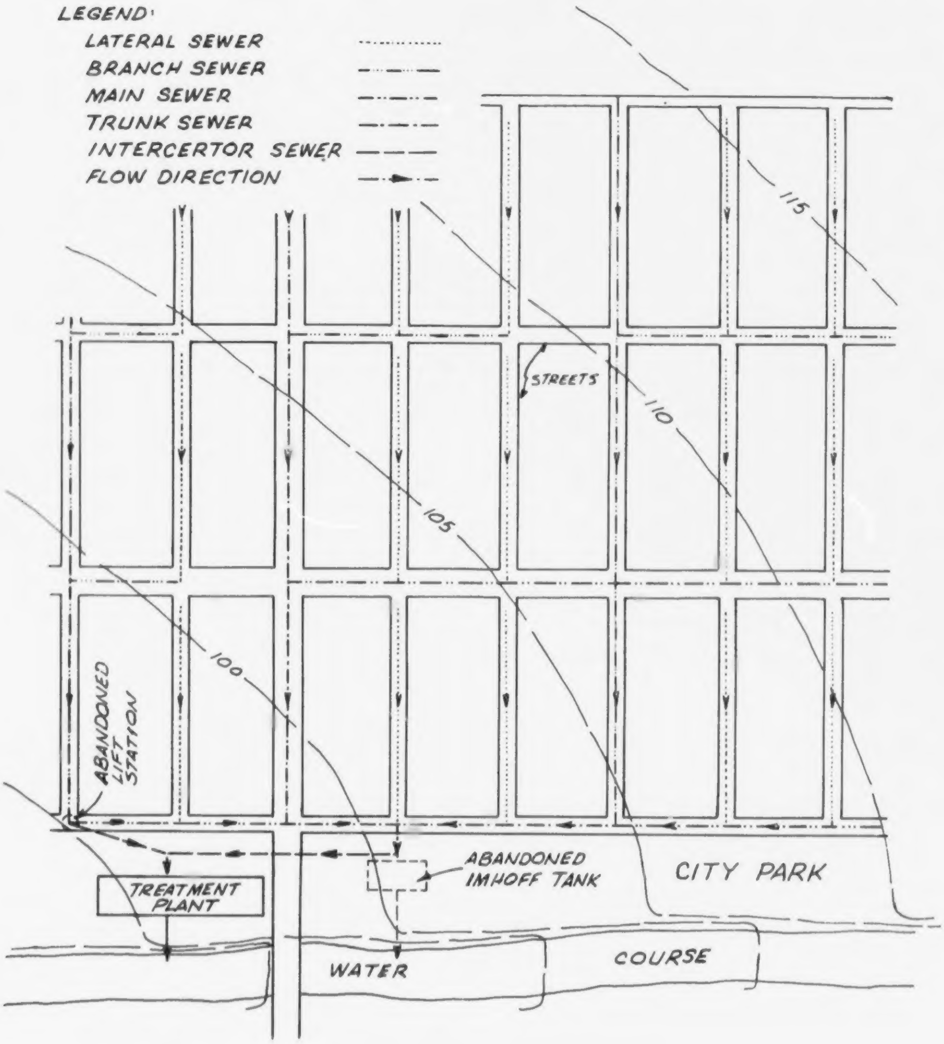

LEGEND:
LATERAL SEWER
BRANCH SEWER
MAIN SEWER
TRUNK SEWER
INTERCERTOR SEWER
FLOW DIRECTION
115
110
105
100
STREETS
ABANDONED LIFT STATION
TREATMENT PLANT
ABANDONED IMHOFF TANK
CITY PARK
WATER
COURSE

Fig. 3.3 Schematic of a typical gravity wastewater collection system

LIFT STATIONS are used in a gravity collection system to lift (pump) wastewater to a higher elevation when the slope of the route followed by a gravity sewer would cause the sewer to be laid at an insufficient slope or at an impractical depth. Lift stations vary in size and type depending on the quantity and height the wastewater is to be lifted. Chapter 8 in Volume II of this manual describes the sizes and types of lift stations.

3.31 Low Pressure Collection Systems

Where the topography and ground conditions of an area are not suitable for a conventional gravity collection system due to flat terrain, rocky conditions or extremely high groundwater, low pressure collection systems are now becoming a practical alternative. Pressure sewers may be installed instead of gravity sewers in an area because (1) a pipe slope is not practical to maintain gravity flow, (2) smaller pipe sizes can be used due to pressurization, and (3) reduced pipe sizes can be installed due to a lack of infiltration and inflow because the pipeline has no leaks and water does not enter the system through access manholes. Operation and maintenance considerations when comparing pressure sewers with gravity systems include the facts that pressure systems have (1) higher energy costs for pumping, (2) greater costs for pumping facilities, (3) less stoppages, (4) no root intrusion, (5) no extra capacity for infiltration and inflow, (6) no deep trenches or buried pipe, and (7) no inverted siphons for crossing roads or rivers. The principal components of a low pressure collection system include gravity sewers, holding tanks, grinder pumps and pressure mains.

GRAVITY SEWERS connect a building's wastewater drainage system to a buried holding tank located on the lot as illustrated in Figure 3.4.

HOLDING TANKS serve as a reservoir for grinder pumps and have a capacity of approximately 50 gallons. Figure 3.4 illustrates a typical holding tank.

GRINDER PUMPS serve both as a unit to grind the solids in the wastewater (that could plug the downstream small-diameter pressure sewers and valves) and to pressurize the wastewater to help move it through the collection system. Figure 3.4 illustrates the location of the submersible grinder pump in the holding tank.

PRESSURE MAINS are the "arteries" of the low pressure collection system and convey the pressurized wastewater to a treatment plant. Since the wastewater is "pushed" by pressure, the mains are not dependent on a slope to create a gravity flow and can be laid at a uniform depth following the natural slope of the land along their routes. Low pressure collection systems must have access for maintenance. This means line access where a *PIG*[8] (see Chapter 6) can be inserted into a line for cleaning and also removed from the line. Manholes or boxes must have valves and pipe spools (two to three foot long flanged sections of pipe) that can be removed for cleaning the pipe or for pumping into or out of the system with a portable pump. Figure 3.5 illustrates the profile of a typical low pressure main and Figure 3.6 illustrates a typical low pressure collection system.

3.32 Vacuum Collection System

Vacuum collection systems are also being used as an alternative to a gravity collection system. These vacuum systems are installed for the same reasons that low pressure collection systems are used. Operation and maintenance of vacuum systems are more difficult than low pressure systems because it is harder to maintain a vacuum due to the number of inlets and valves to the system. Principal components of a vacuum collection system include gravity sewers, holding tanks, vacuum valves, vacuum mains and vacuum pumps.

GRAVITY SEWERS connect a building's wastewater drainage system to a vacuum interface unit as illustrated in Figure 3.7. [INSERT FIGURE 3.7 HERE]

VACUUM INTERFACE UNIT seals the vacuum service and connects the vacuum sewer to the gravity flow system from a home. This unit maintains the required vacuum level in the main vacuum sewer system. When approximately three gallons of wastewater has accumulated at the vacuum interface unit, a valve is activated which allows atmospheric air pressure to force the wastewater into the vacuum branch. The location of the interface unit is shown in Figure 3.7.

VACUUM MAINS are the "arteries" of a vacuum collection system and convey the wastewater to a treatment plant. Since the wastewater is "sucked" by vacuum, the collection mains do not have to be laid at a slope to produce a gravity pull on the wastewater and the mains may be laid at a uniform depth following the natural slope of their routes.

VACUUM PUMPS are installed in a central station usually adjacent to a treatment plant and maintain the appropriate vacuum in the main collection system. Access must be provided for maintenance.

Figure 3.8 illustrates a typical street portion of a vacuum collection system and an overview of the entire collection system.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 66.

3.3A List the parts or components of a gravity wastewater collection system.

3.3B List the principal components of a low pressure collection system.

3.3C List the principal components of a vacuum collection system.

3.33 Appurtenances

The immediately preceding sections of this chapter described the principal components of a wastewater collection system consisting primarily of sewer piping and pumps. This section will describe the appurtenances to a collection system that facilitate and control the flow of wastewater and provide for the access to maintain the collection systems.

BACKFLOW PREVENTERS are used to stop the accidental backflow or reverse flow of wastewater into buildings. They function by either allowing wastewater to flow out of a building sewer at a point outside and below the floor elevation of a building or by blocking the backflow of wastewater from the sewer into the building sewer by a one-way hinged valve (check valve). The two types of backflow preventers and their location in a building sewer are illustrated in Figure 3.9. Backflow preventers are used when the lowest overflow point in a building's wastewater drainage system is below the rim elevation of the manhole in the lateral or main sewer immediately upstream of the building sewer connection.

---

[8] *Pig. Refers to a poly pig which is bullet shaped and made of hard rubber or similar material.*

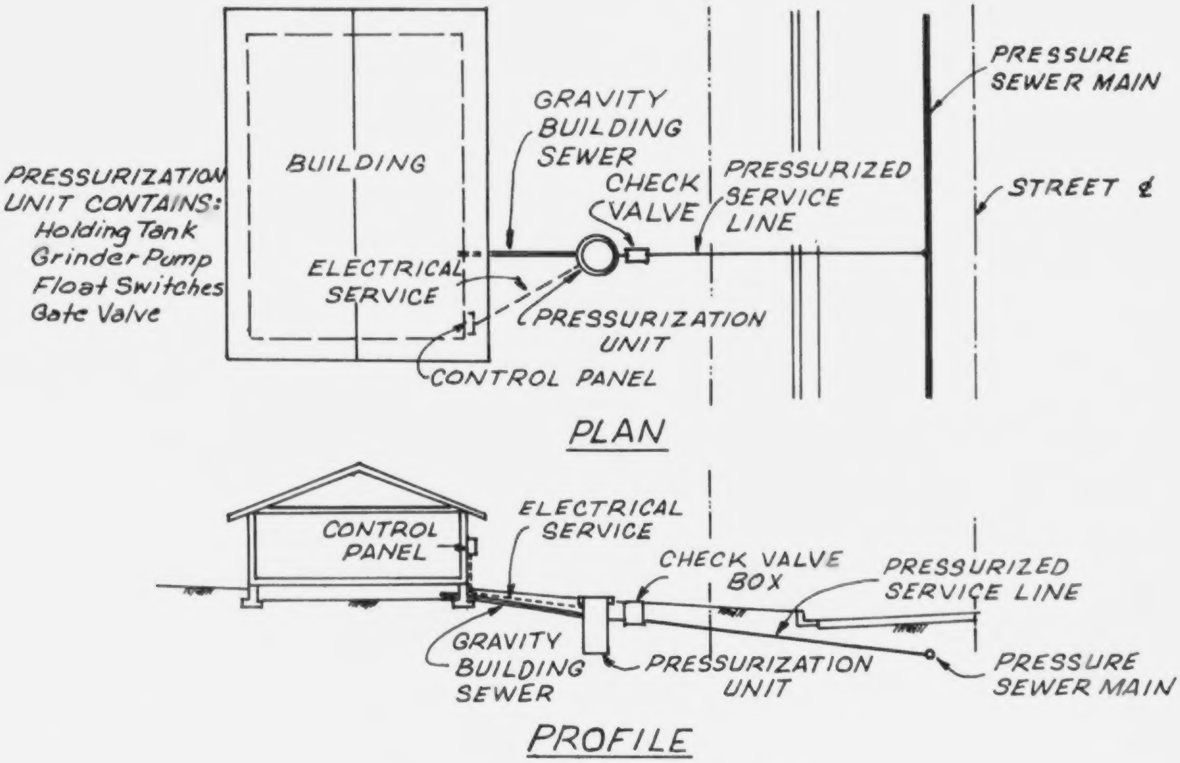

PRESSURIZATION UNIT CONTAINS:
Holding Tank
Grinder Pump
Float Switches
Gate Valve
BUILDING
ELECTRICAL SERVICE
CONTROL PANEL
GRAVITY BUILDING SEWER
CHECK VALVE
PRESSURIZATION UNIT
PRESSURIZED SERVICE LINE
PRESSURE SEWER MAIN
STREET ℄
PLAN
CONTROL PANEL
ELECTRICAL SERVICE
CHECK VALVE BOX
PRESSURIZED SERVICE LINE
GRAVITY BUILDING SEWER
PRESSURIZATION UNIT
PRESSURE SEWER MAIN
PROFILE

Fig. 3.4 Principal components of a typical low pressure collection system

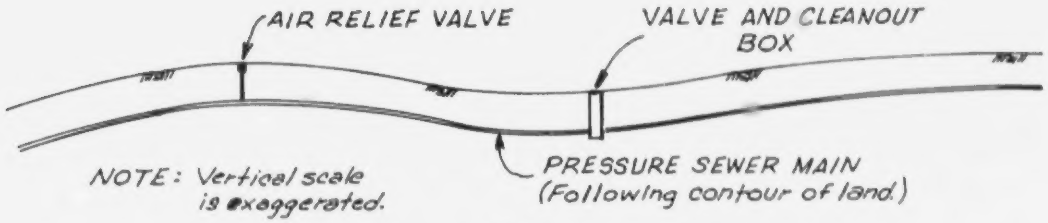

AIR RELIEF VALVE
VALVE AND CLEANOUT BOX
NOTE: Vertical scale is exaggerated.
PRESSURE SEWER MAIN (Following contour of land)

Fig. 3.5 Profile of a typical low pressure main

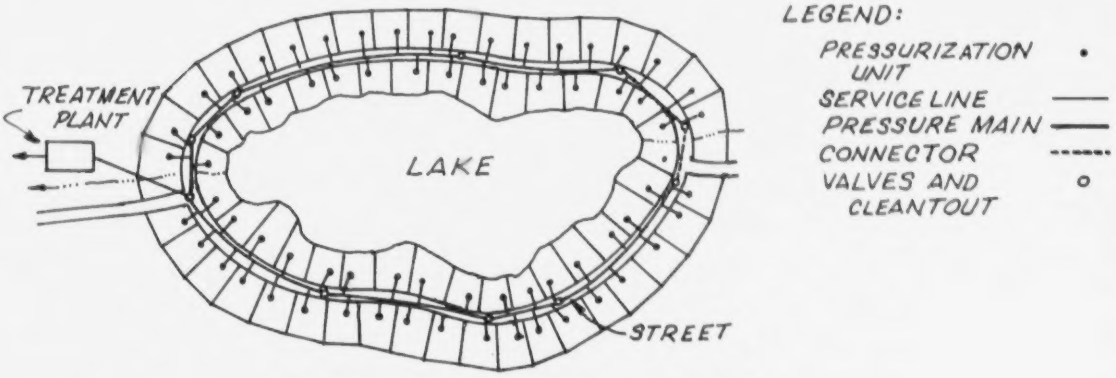

TREATMENT PLANT
LAKE
STREET
LEGEND:
PRESSURIZATION UNIT •
SERVICE LINE
PRESSURE MAIN
CONNECTOR
VALVES AND CLEANTOUT ○

Fig. 3.6 Schematic of a typical low pressure collection system

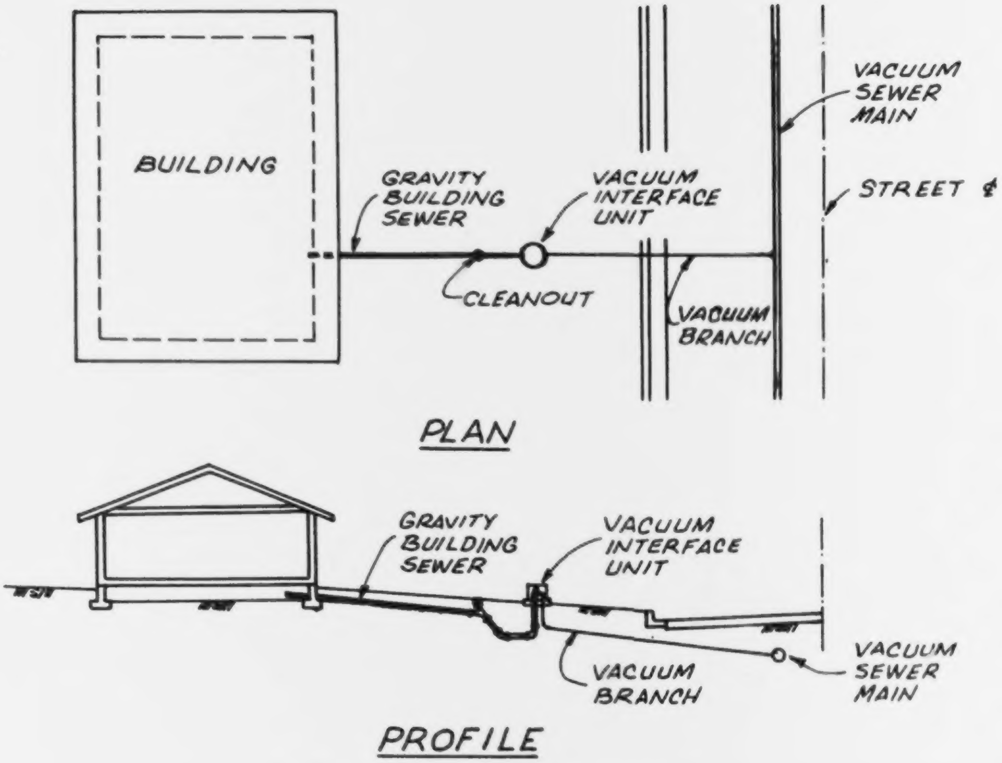

BUILDING
GRAVITY BUILDING SEWER
VACUUM INTERFACE UNIT
CLEANOUT
VACUUM BRANCH
VACUUM SEWER MAIN
STREET ¢
PLAN
GRAVITY BUILDING SEWER
VACUUM INTERFACE UNIT
VACUUM BRANCH
VACUUM SEWER MAIN
PROFILE

Fig. 3.7 Principal components of a typical vacuum collection system

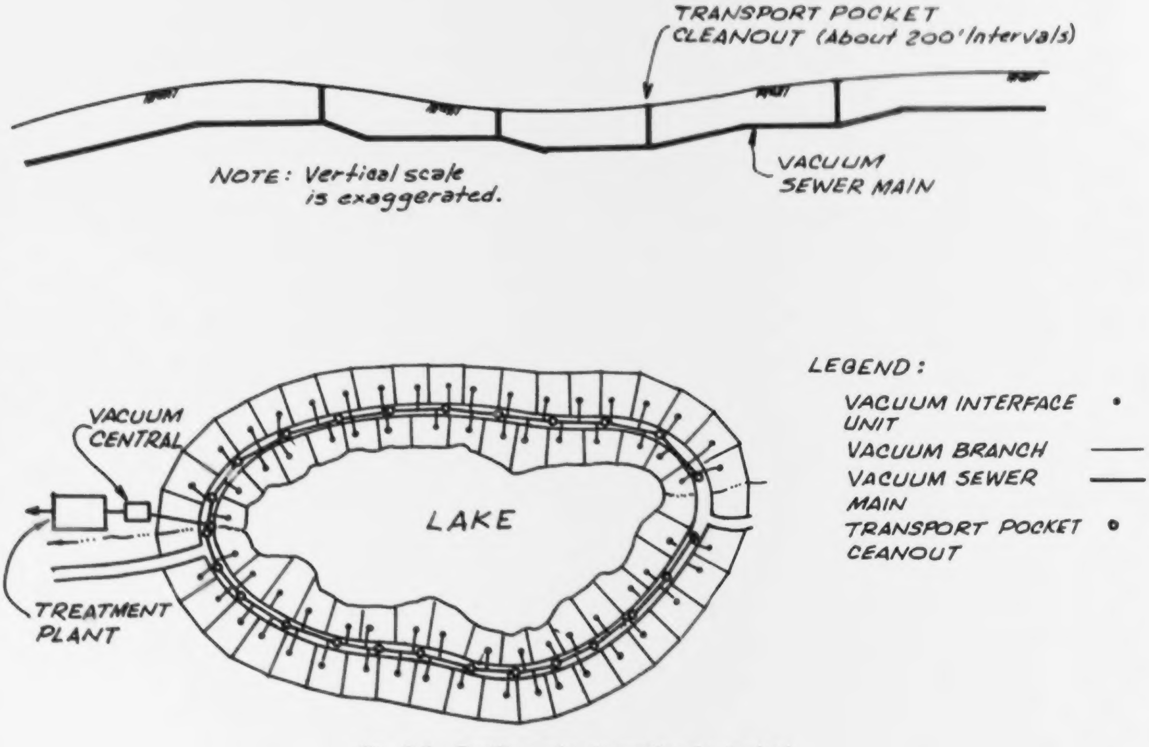
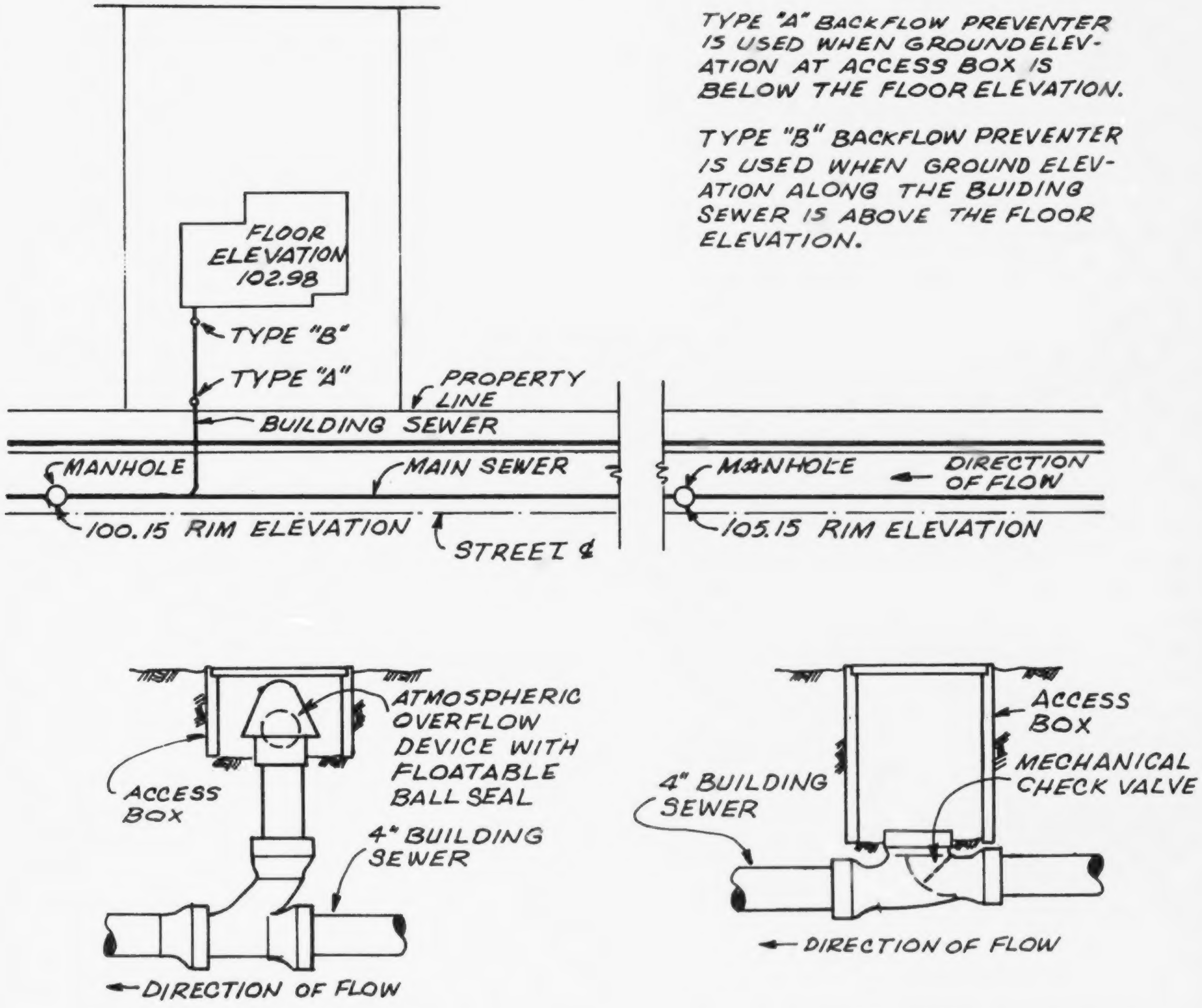

TRANSPORT POCKET CLEANOUT (About 200' Intervals)
NOTE: Vertical scale is exaggerated.
VACUUM SEWER MAIN
VACUUM CENTRAL
LAKE
TREATMENT PLANT
LEGEND:
VACUUM INTERFACE UNIT •
VACUUM BRANCH —
VACUUM SEWER MAIN —
TRANSPORT POCKET CEANOUT ○

Fig. 3.8 Profile and schematic of a typical vacuum collection system


TYPE "A" BACKFLOW PREVENTER IS USED WHEN GROUND ELEVATION AT ACCESS BOX IS BELOW THE FLOOR ELEVATION.
TYPE "B" BACKFLOW PREVENTER IS USED WHEN GROUND ELEVATION ALONG THE BUIDING SEWER IS ABOVE THE FLOOR ELEVATION.
FLOOR ELEVATION 102.98
TYPE "B"
TYPE "A"
PROPERTY LINE
BUILDING SEWER
MANHOLE
MAIN SEWER
100.15 RIM ELEVATION
STREET ℄
MANHOLE
DIRECTION OF FLOW
105.15 RIM ELEVATION
ATMOSPHERIC OVERFLOW DEVICE WITH FLOATABLE BALL SEAL
ACCESS BOX
4" BUILDING SEWER
DIRECTION OF FLOW
ACCESS BOX
MECHANICAL CHECK VALVE
4" BUILDING SEWER
DIRECTION OF FLOW

TYPE "A" BACKFLOW PREVENTER

TYPE "B" BACKFLOW PREVENTER

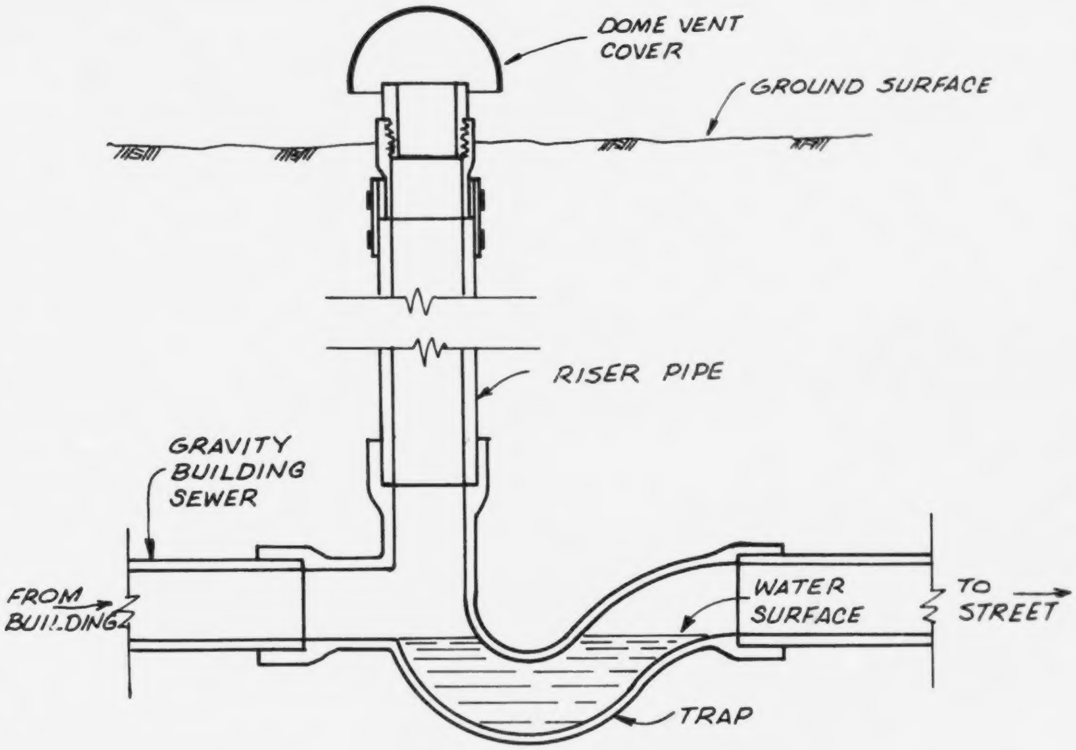
NOTE: There should be a written agreement between the property owner and the sewer district regarding who is responsible for the maintenance of backflow preventers. Grease deposits or rags can prevent their proper operation and they should be cleaned every six months.

Fig. 3.9 Location and type of wastewater backflow preventers

BUILDING SEWER VENT TRAPS[9] are used to prevent the passage of gases and odors from the main sewer system into a building's wastewater plumbing (drainage) system. They are not used extensively today since plumbing codes require adequate trapping and venting of a building's plumbing fixtures and because the traps tend to collect solids, thus causing stoppages in the building sewer. Also, removal of stoppages in a building sewer is made more difficult since cleaning equipment must negotiate the bends in the trap as illustrated in Figure 3.10. If vent traps are not properly screened, they can allow rodents access to building sewers and the collection system. Also, if traps are located in a low spot in a yard, this will serve as a source of inflow from surface runoff. Vent traps in low spots should be removed and adequate venting installed in the home or building.

---

[9] *Also called handhole trap, vent trap, main trap or house trap.*



NOTE: A screen must be installed in the dome to prevent entry by rodents.

Fig. 3.10 Building sewer vent trap

BUILDING SEWER CLEANOUTS are located as required by local building codes and sewer ordinances. They are used to allow access to sewers to remove solids which cause stoppages. As a minimum, a cleanout should be located in the building sewer approximately three feet from the building foundation and another at the building's property line if the part of the sewer in the street is maintained by a sewer agency. In very cold climates building sewers are usually placed below the frost line and cleanouts are located in the inside wall of basements to provide convenient access in the winter. Figure 3.11 illustrates the types and locations of cleanouts in building sewers.

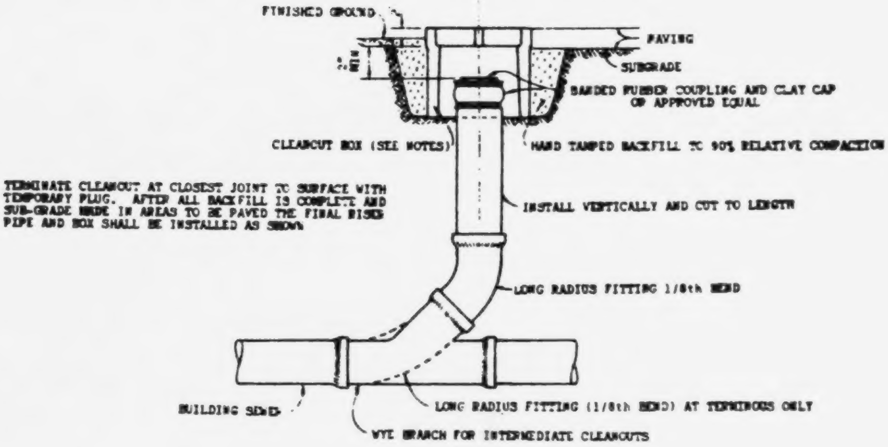
BUILDING SEWER CONNECTIONS (also called TAPS) to street sewers are either provided during construction of these sewers, if the appropriate location is known, or after their construction. In either instance they should be constructed with care since these connections can be a source of groundwater infiltration and sewer stoppages if not constructed properly. The taps must not protrude into the street sewer. Figure 3.12 illustrates the types of building sewer connections.

LATERAL AND BRANCH SEWER CLEANOUTS are sometimes placed at the terminals of these sewers, in place of manholes, to provide a means of inserting cleaning equipment and water for flushing the line in some instances. Typical cleanouts are illustrated in Figures 3.13 and 3.14. The slant riser provides easier access to the lateral or branch sewer, but the impact of street traffic on the frame and cover tend to shear the cleanout pipe below the frame.

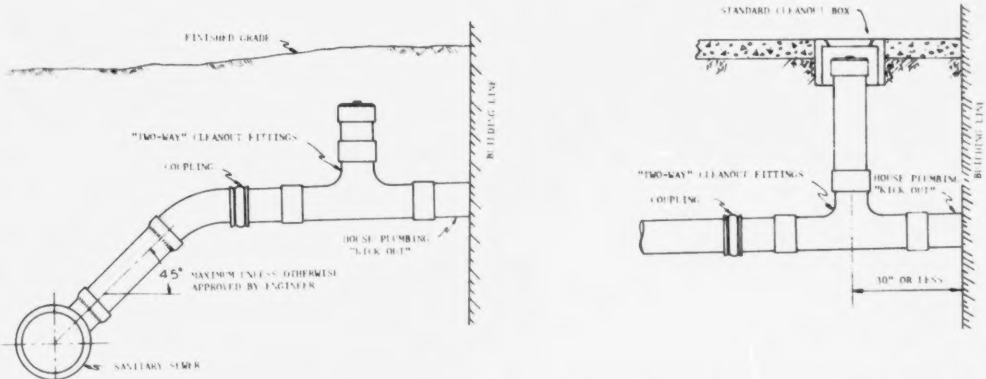
FLUSHER BRANCHES were used in the past for the introduction of large volumes of water in the upper ends of lateral and branch sewers to attempt to move deposited solids downstream to self- cleaning sewers. Those that still exist are similar to the vertical and slant lateral sewer cleanouts illustrated in Figures 3.13 and 3.14. However, other sewer cleaning methods are more effective than flushing and flusher branches are not used very often today.

LAMP HOLES are rarely found today. They are similar to a vertical lateral sewer cleanout. Lamp holes were placed midway between adjacent manholes for the introduction of a lamp that would be viewed through the sewer line from the manholes to determine if the sewer line was free of solids or breaks that could cause a stoppage of the wastewater flow. The use of modern sewer line viewing methods, such as closed circuit television, have made lamp holes obsolete. However, they may still exist in older collection systems where they should be sealed to prevent surface inflow.

MANHOLES are installed in lateral, main, trunk and intercepting sewers for the purpose of placing persons, equipment and materials into these sewers for inspection, maintenance and the removal of solids from cleaning operations. Manholes in straight runs of sewer lines should be spaced no farther apart than the distance that can be cleaned by the appropriate type of equipment (usually 300 to 500 feet). Manholes are also placed at changes in sewer line direction, slope, elevation, pipe sizes and junctions. Drop manholes are used when the difference in the elevation of an incoming and outgoing sewer line cannot be accommodated by a drop in the manhole channel without creating excessive turbu-

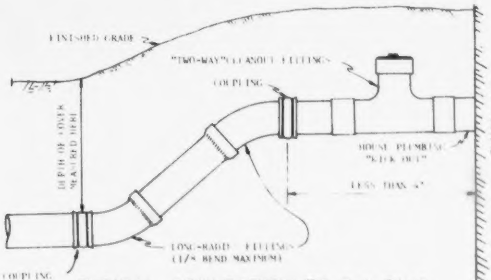

FINISHED GROUND
PAVING
SUBGRADE
BANDED RUBBER COUPLING AND CLAY CAP OR APPROVED EQUAL
CLEANOUT BOX (SEE NOTES)
HAND TAMPED BACKFILL TO 90% RELATIVE COMPACTION
TERMINATE CLEANOUT AT CLOSEST JOINT TO SURFACE WITH TEMPORARY PLUG. AFTER ALL BACKFILL IS COMPLETE AND SUB-GRADE MADE IN AREAS TO BE PAVED THE FINAL RISER PIPE AND BOX SHALL BE INSTALLED AS SHOWN
INSTALL VERTICALLY AND CUT TO LENGTH
LONG RADIUS FITTING 1/8th BEND
BUILDING SEWER
LONG RADIUS FITTING (1/8th BEND) AT TERMINOUS ONLY
WYE BRANCH FOR INTERMEDIATE CLEANOUTS

CLEANOUT AT PROPERTY LINE


FINISHED GRADE
"TWO-WAY" CLEANOUT FITTINGS
COUPLING
BUILDING LINE
HOUSE PLUMBING "KICK OUT"
45° MAXIMUM UNLESS OTHERWISE APPROVED BY ENGINEER
SANITARY SEWER
STANDARD CLEANOUT BOX
"TWO-WAY" CLEANOUT FITTINGS
COUPLING
HOUSE PLUMBING "KICK OUT"
BUILDING LINE
30" OR LESS

TYPICAL CONNECTION TO DEEPER LONGITUDINAL BUILDING SEWER.

TYPICAL "TWO-WAY" CLEANOUT TO GRADE.
(ALL RESIDENTIAL USES WHEN UNDER PAVING AND/OR COVERED AREA; AND FOR ALL INDUSTRIAL AND COMMERCIAL USES.)

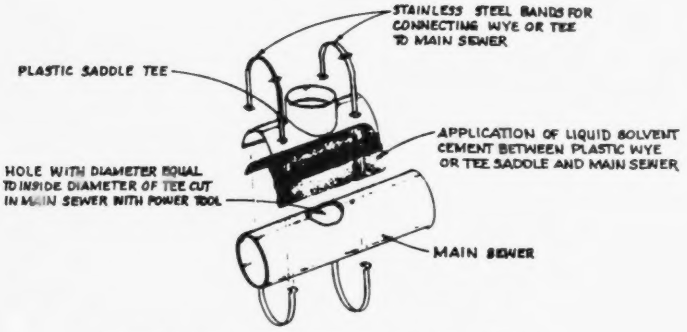

FINISHED GRADE
"TWO-WAY" CLEANOUT FITTINGS
COUPLING
DEPTH OF COVER MEASURED HERE
HOUSE PLUMBING "KICK OUT"
BUILDING LINE
LESS THAN 4'
LONG-RADIUS FITTINGS (1/8 BEND MAXIMUM)
COUPLING

TYPICAL CONNECTION TO BUILDING SEWER WHERE ADDITIONAL DEPTH IS REQUIRED.

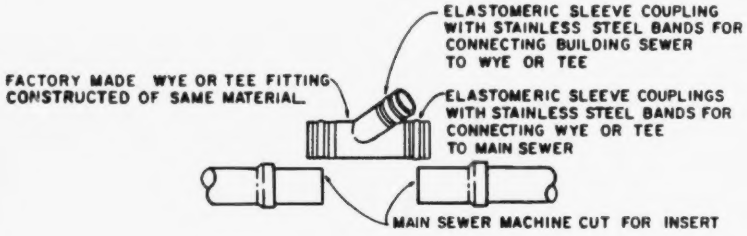
NOTES: 1. Cleanouts should be extended to surface so they are accessible without excavation in order to reduce maintenance costs and customer complaints regarding operators messing up their yards.

"Two-Way" cleanout fittings may be difficult to push equipment through because of the right-angle entrance instead of a gradual entrance.

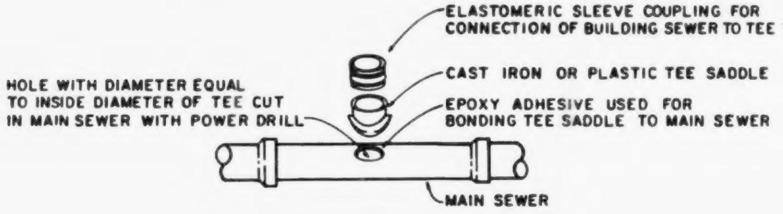
Fig. 3.11 Types and location of building sewer cleanouts


STAINLESS STEEL BANDS FOR CONNECTING WYE OR TEE TO MAIN SEWER
PLASTIC SADDLE TEE
APPLICATION OF LIQUID SOLVENT CEMENT BETWEEN PLASTIC WYE OR TEE SADDLE AND MAIN SEWER
HOLE WITH DIAMETER EQUAL TO INSIDE DIAMETER OF TEE CUT IN MAIN SEWER WITH POWER TOOL
MAIN SEWER

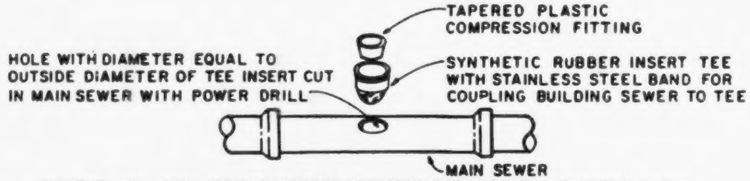
SADDLE TEE CEMENTED TO PLASTIC PIPE


ELASTOMERIC SLEEVE COUPLING WITH STAINLESS STEEL BANDS FOR CONNECTING BUILDING SEWER TO WYE OR TEE
FACTORY MADE WYE OR TEE FITTING CONSTRUCTED OF SAME MATERIAL
ELASTOMERIC SLEEVE COUPLINGS WITH STAINLESS STEEL BANDS FOR CONNECTING WYE OR TEE TO MAIN SEWER
MAIN SEWER MACHINE CUT FOR INSERT

INSERTION OF FACTORY MADE WYE OR TEE


ELASTOMERIC SLEEVE COUPLING FOR CONNECTION OF BUILDING SEWER TO TEE
CAST IRON OR PLASTIC TEE SADDLE
HOLE WITH DIAMETER EQUAL TO INSIDE DIAMETER OF TEE CUT IN MAIN SEWER WITH POWER DRILL
EPOXY ADHESIVE USED FOR BONDING TEE SADDLE TO MAIN SEWER
MAIN SEWER

EPOXY BONDED SADDLE TEE


TAPERED PLASTIC COMPRESSION FITTING
HOLE WITH DIAMETER EQUAL TO OUTSIDE DIAMETER OF TEE INSERT CUT IN MAIN SEWER WITH POWER DRILL
SYNTHETIC RUBBER INSERT TEE WITH STAINLESS STEEL BAND FOR COUPLING BUILDING SEWER TO TEE
MAIN SEWER

DISTRICT WILL REQUIRE THE WEDGED INSERTED TEE INTO THE EXISTING RIGID MAIN SEWERS UNLESS OTHERWISE DIRECTED BY DISTRICT ENGINEER

SYNTHETIC RUBBER WEDGED INSERT TEE

Fig. 3.12 Building sewer connections (taps)

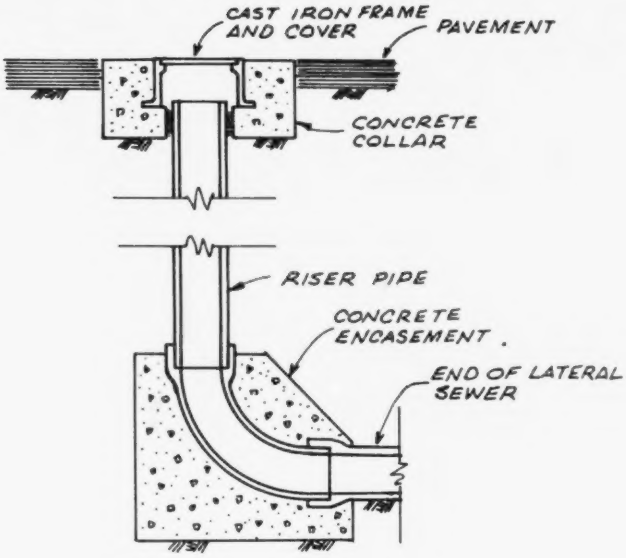

CAST IRON FRAME AND COVER
PAVEMENT
CONCRETE COLLAR
RISER PIPE
CONCRETE ENCASEMENT
END OF LATERAL SEWER

Fig. 3.13 Vertical lateral cleanout

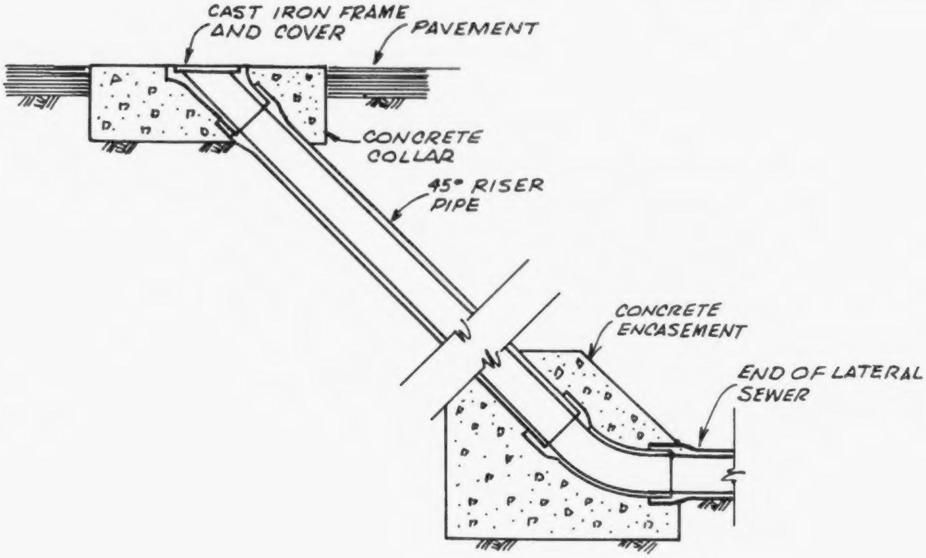

CAST IRON FRAME AND COVER
PAVEMENT
CONCRETE COLLAR
45° RISER PIPE
CONCRETE ENCASEMENT
END OF LATERAL SEWER

Fig. 3.14 Slant lateral cleanout

lence and splashing of wastewater. Manholes may be furnished with or without steps depending upon the practice of a sewer agency. Some agencies prefer to use ladders for entry and exit of manholes for safety reasons. Deterioration caused by corrosion could cause the steps to fail when the operator tries to use them. Figure 3.15 illustrates a typical manhole, including a drop structure, for sewers up to 24-inches in diameter. Larger diameter sewers require modification of the base and channel. However, the barrel, frame and cover usually remain similar to the illustration.

JUNCTION STRUCTURES are used to join large diameter trunk sewers when the junction cannot be made in a manhole. The structure usually contains facilities for the regulation of wastewater flows in the sewers running out of the junction as illustrated in Figure 3.16. Flow of wastewater through the structure should not produce undesirable turbulence that could release hydrogen sulfide or create a partial blockage of the incoming wastewater. Hydrogen sulfide smells like rotten eggs, is a toxic gas and forms corrosive sulfuric acid when combined with moisture in sewers.

INTERCONNECTOR SEWERS are short sewer lines that run between adjacent manholes to allow the regulation of wastewater flows in parallel sewers or the automatic diversion of wastewater to an alternate sewer if the primary sewer becomes blocked. Although the automatic diversion of wastewater from a blocked sewer may protect buildings from wastewater overflow, this type of diversion requires periodic inspection to determine if the primary sewer is blocked. If the wastewater in the primary sewer is blocked, it may become *SEPTIC*[10] and cause odors.

INVERTED SIPHONS are sewer lines installed lower than the normal gradient of the sewer line to pass under obstructions such as water courses and depressed roadways as illustrated in Figure 3.17. Wastewater is "pushed" through the siphon by the pressure resulting from the upstream sewer (at the junction manhole) being higher than the downstream sewer. Siphons generally require more maintenance than gravity sewers since solids in the conveyed wastewater must be pushed up the downstream leg of the siphon by the velocity of the wastewater. Low velocities will leave heavy solids at the bottom of the siphon and these must be removed by one of several cleaning methods. For this reason, siphons are sometimes constructed with two parallel barrels (pipes) to provide an alternative route for the wastewater if one barrel becomes blocked.

AIR JUMPERS are sometimes constructed as part of an inverted siphon as illustrated in Figure 3.17. Since the siphon is completely filled with wastewater, a blockage in the flow of air in the sewer line occurs without an air jumper. Continuation of the air flow is important if its stoppage would cause a corrosive, odorous or toxic release of hydrogen sulfide at the upstream siphon manhole. Installation of air jumpers prevents this from happening by providing the downstream flow of air that usually occurs above the wastewater in a partially filled sewer line.

FLOW REGULATORS in a wastewater collection system are used to divert the flow of wastewater from one sewer line to another for the efficient use of the system and to prevent overloading one portion of the system. The regulators are usually simple in nature with a minimum of moving parts due to the nature of wastewater. Weirs are used in manholes and junction structure channels, as illustrated in Figures 3.16 and 3.18, to regulate the flow of wastewater in the multiple sewers as appropriate for operating conditions. The weirs are simply boards of an appropriate height that are inserted in preformed slots in the channels. Another simple flow regulator is the Hydro-Brake recently developed by Hydro Research & Development; it is illustrated in Figure 3.19. The Brake imparts a centrifugal (moving outward from center) motion to the entering wastewater when a predetermined depth has been reached. This action effectively reduces the rate of discharge. The Brake can also be used as an energy dissipator to reduce turbulence at the lower end of a steep section of sewer line.

QUESTIONS

Write your anwers in a notebook and then compare your answers with those on page 66.

3.3D What is the purpose of a backflow preventer?

3.3E List the two major types of wastewater backflow preventers.

3.3F What are inverted siphons?

3.3G What is the purpose of flow regulators in wastewater collection systems?

3.4 DESIGN

Collection system operators need to be familiar with the elements of a wastewater collection system design that have an influence on the operation and maintenance (O & M) of the constructed system. This familiarity will allow an operator to effectively review the plans and specifications for newly designed collection systems to minimize later maintenance and to understand problems in existing collection systems caused by improper or unnecessary design factors. When operators review designs they should, for example, make sure that manholes are located in accessible locations and that overhead power lines and highway overpasses will not interfere with cranes used to lift pumps or other activities. Also manholes should not be located in dry creek beds or the middle of major streets or highways.

3.40 Layout

A layout of a wastewater collection system shows the general location of laterals, mains and trunk sewers within the service area, as illustrated by Figure 3.3 on page 43. The layout shows the direction of flow in the sewer system based on the contours of the area, but does not indicate the size or slope of sewer lines which are unknown at the time a layout is prepared.

3.41 Field Surveys

Field surveys are conducted by engineers to record the location of the physical features and the elevation of the ground surface along the planned route of the sewer lines in the collection system. Physical information includes location and elevations of buildings to be served, surface improvements (such as sidewalks and street pavement), location of surface and underground utilities (gas, electricity, phone) and other items that will influence the location of a sewer line. Field surveys include both route surveys and level surveys.

ROUTE SURVEYS pinpoint the location of physical features that will influence the horizontal location of a sewer

---

[10] *Septic (SEP-tick). This condition is produced by anaerobic bacteria. If severe, the wastewater turns black, gives off foul odors, contains little or no dissolved oxygen, and creates a high oxygen demand.*

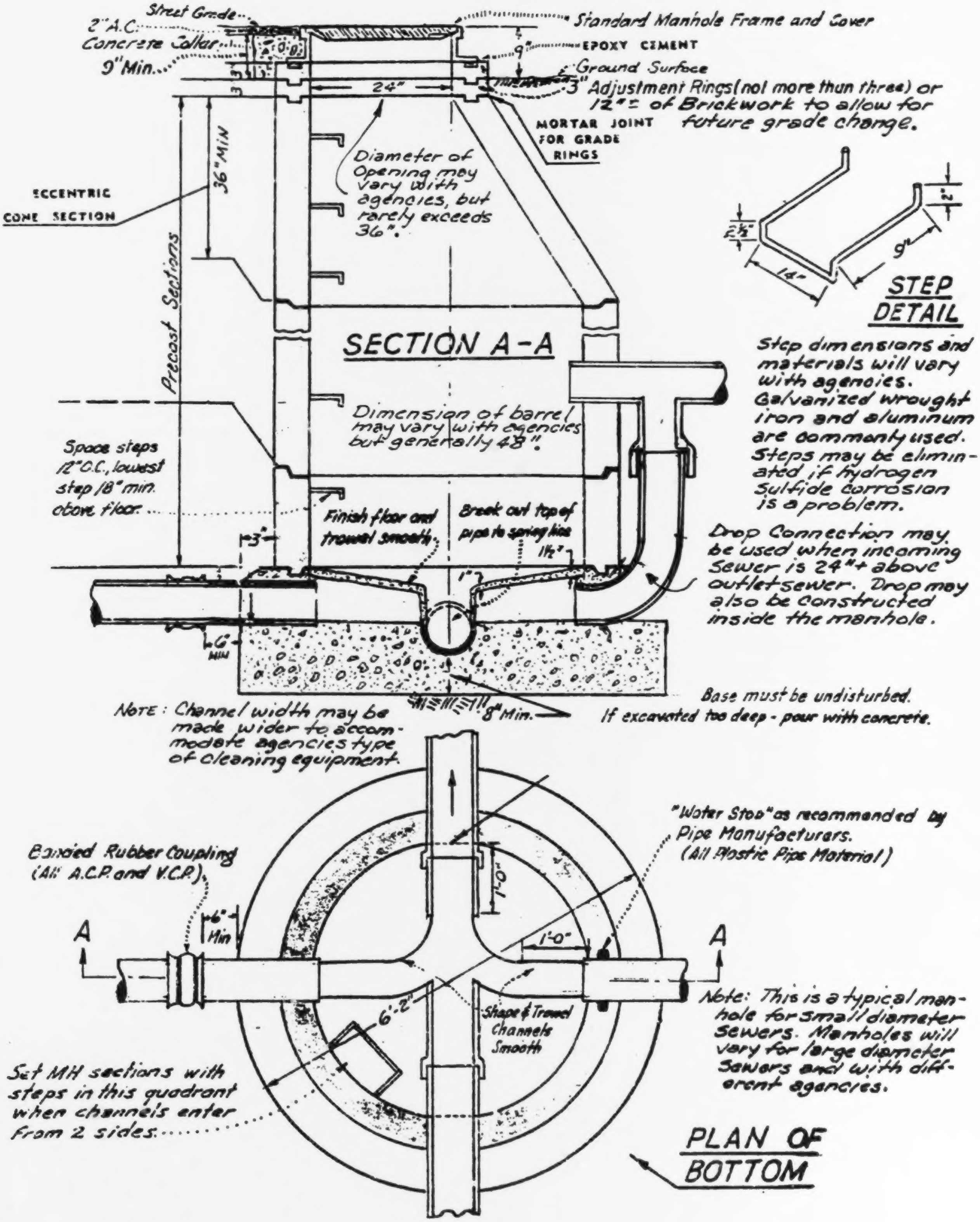

Street Grade
2" A.C.
Concrete Collar
9" Min.
Standard Manhole Frame and Cover
4"
9"
EPOXY CEMENT
Ground Surface
3" Adjustment Rings (not more than three) or 12" ± of Brickwork to allow for future grade change.
3
3
24"
MORTAR JOINT FOR GRADE RINGS
ECCENTRIC CONE SECTION
36" MIN
Diameter of Opening may vary with agencies, but rarely exceeds 36".
Precast Sections
SECTION A-A
Dimension of barrel may vary with agencies but generally 48".
Space steps 12" O.C., lowest step 18" min. above floor.
3"
Finish floor and trowel smooth
Break out top of pipe to spring line
1½"
1"
6" MIN
8" Min.
Base must be undisturbed. If excavated too deep - pour with concrete.
NOTE: Channel width may be made wider to accommodate agencies type of cleaning equipment.
Drop Connection may be used when incoming Sewer is 24"+ above outlet sewer. Drop may also be constructed inside the manhole.
2"
2½"
9"
14"
STEP DETAIL
Step dimensions and materials will vary with agencies. Galvanized wrought iron and aluminum are commonly used. Steps may be eliminated if hydrogen Sulfide corrosion is a problem.
"Water Stop" as recommended by Pipe Manufacturers. (All Plastic Pipe Material)
Banded Rubber Coupling (All A.C.P. and V.C.P.)
6" Min
A
A
1'-0"
1'-0"
6'-2"
Shape & Trowel Channels Smooth
Set MH sections with steps in this quadrant when channels enter from 2 sides.
Note: This is a typical manhole for small diameter sewers. Manholes will vary for large diameter sewers and with different agencies.
PLAN OF BOTTOM

Fig. 3.15 Precast concrete manhole

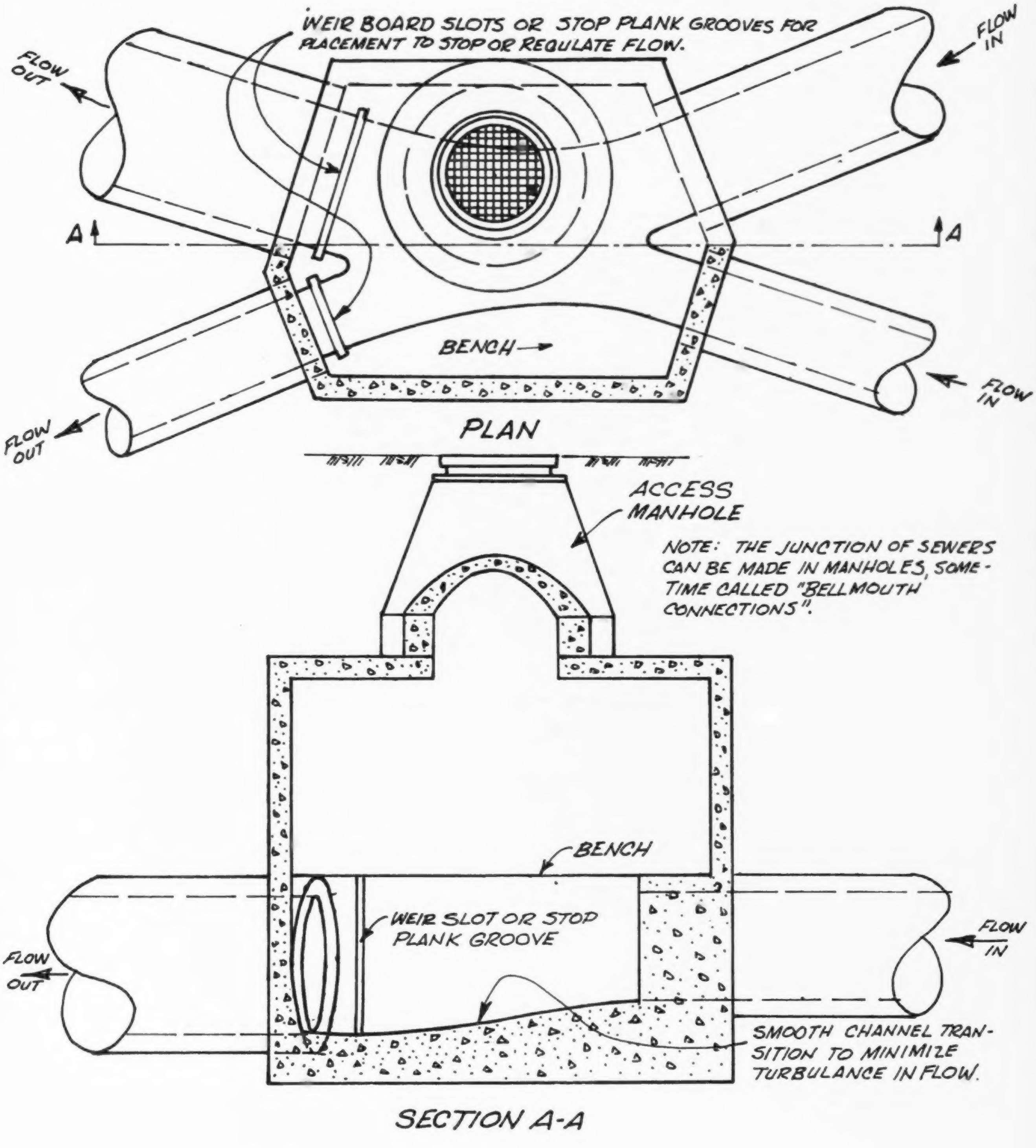
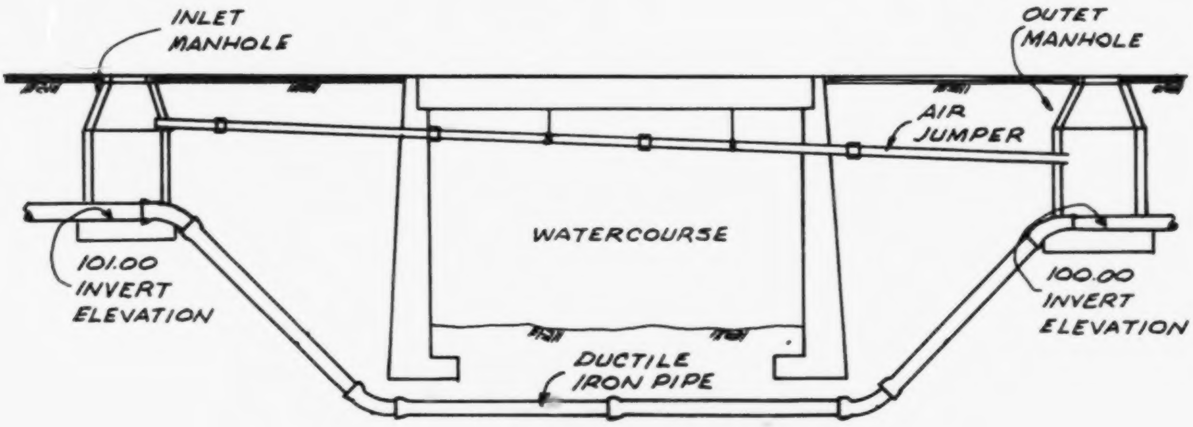

WEIR BOARD SLOTS OR STOP PLANK GROOVES FOR PLACEMENT TO STOP OR REGULATE FLOW.
FLOW IN
FLOW OUT
A
A
BENCH
FLOW IN
FLOW OUT
PLAN
ACCESS MANHOLE
NOTE: THE JUNCTION OF SEWERS CAN BE MADE IN MANHOLES, SOME-TIME CALLED "BELLMOUTH CONNECTIONS".
BENCH
WEIR SLOT OR STOP PLANK GROOVE
FLOW IN
FLOW OUT
SMOOTH CHANNEL TRANSITION TO MINIMIZE TURBULANCE IN FLOW.
SECTION A-A

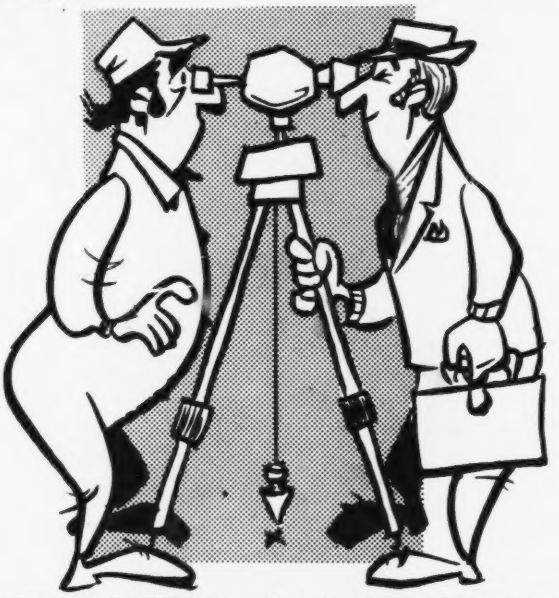
Fig. 3.16 Junction structure



NOTE: INVERTED SIPHONS ARE ARE ALSO USED TO PASS GRAVITY SEWERS UNDER OTHER TYPES OF OBSTRUCTIONS.

Fig. 3.17 Inverted siphon

line. A surveyor's transit and tape are used to locate these features. By using measured angles and taped distances, the exact locations of physical features are referenced to the known location of the transit. Very accurate aerial photographs are sometimes used to determine the location of visible features, with field surveys being limited to the determination of invisible features (such as underground utilities).



LEVEL SURVEYS determine elevations of the ground surface along the route of the sewer line, buildings to be served and (when possible) the elevation of underground obstructions and pipelines.

Since a collection system operator may conduct a level survey for construction or repair of a short section of sewer line, the following section describes the equipment, personnel and procedures used for a level survey.

Personnel

One SURVEYOR and one ASSISTANT.

Equipment

1. Surveyor's level. The level establishes a level line of sight through a 360-degree angle using a horizontal cross-hair in a telescope.
2. Rod. The rod is marked in 0.01-foot (hundredths of a foot) intervals. It is about 7.5 feet long and extendable to 14 feet. The rod is used to measure vertical distances or elevations.

Procedure

1. SURVEYOR: Set the level at a convenient location where back (backward or behind) and fore (forward or ahead) sights can be made. Level the instrument.
2. ASSISTANT. Hold the rod plumb (use the level bubble) on a point of known elevation (a bench mark).
3. SURVEYOR: Back sight (BS) the telescope of the surveyor's level on the rod. Read the distance on the rod that the cross-hair is above the bench mark (5.65 feet in Figure 3.20).
4. SURVEYOR: To determine the height of the instrument (HI) above the bench mark (BM), add the BS distance to the bench mark elevation (HI = BM + BS = 263.47 + 5.65 + 8.20 = 277.32). The 8.20 is the measured distance from the invert elevation of 263.47 to the top of the manhole as shown in Figure 3.20.
5. To determine the elevation of any other point, hold the rod plumb on the point. Fore Sight (FS) the level telescope on the rod and read the distance of the horizontal cross-hair above the point (5.38 feet at station 1 + 00 in Figure 3.20).
6. To calculate the elevation of the point, subtract the FS distance from the HI (EL. 1 + 00 = HI - FS = 277.32 - 5.38 = 271.94).

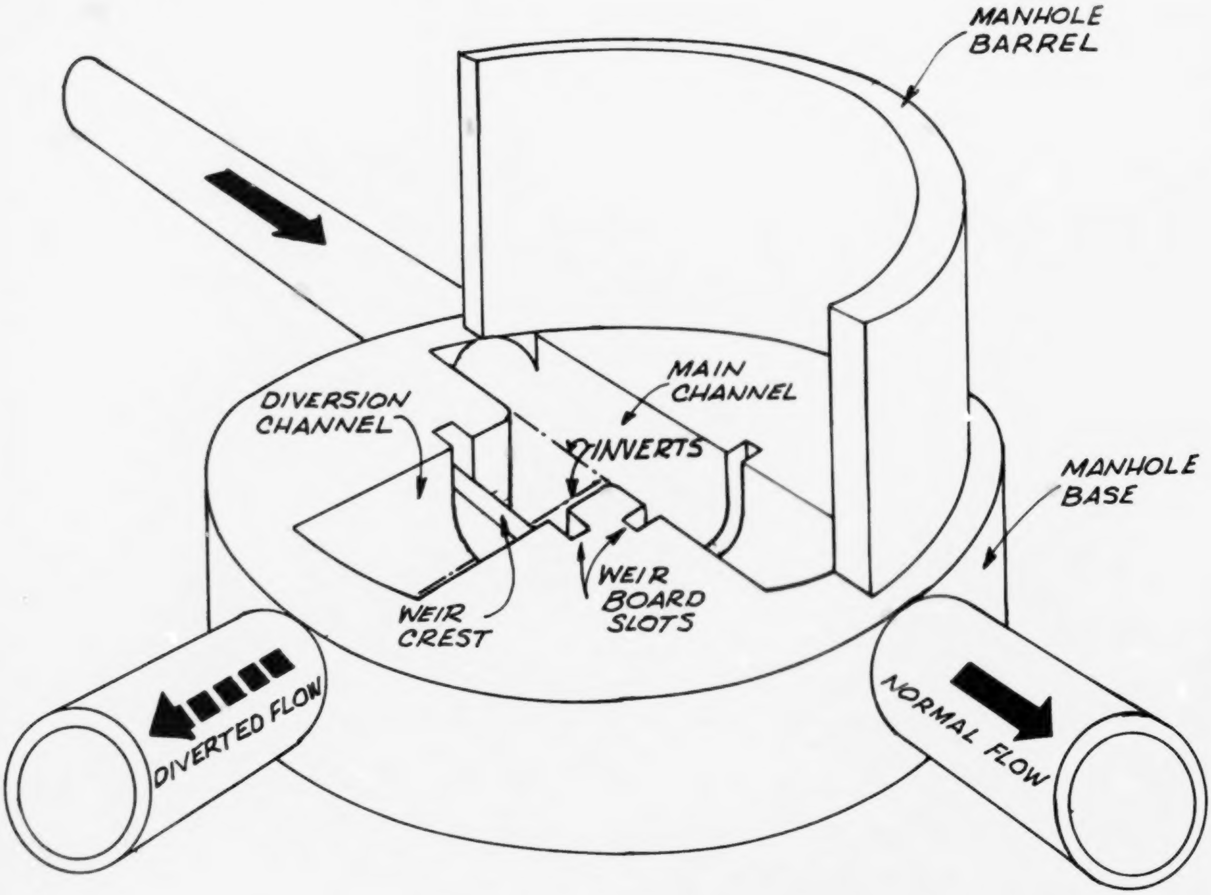

MANHOLE BARREL
DIVERSION CHANNEL
MAIN CHANNEL
INVERTS
MANHOLE BASE
WEIR CREST
WEIR BOARD SLOTS
DIVERTED FLOW
NORMAL FLOW

Fig. 3.18 Typical weir type flow regulator

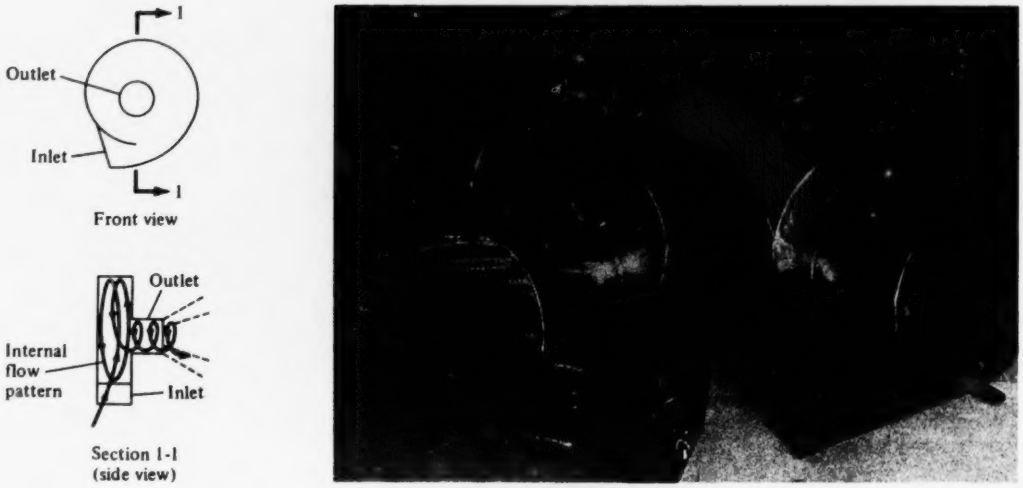

1
Outlet
Inlet
1
Front view
Outlet
Internal flow pattern
Inlet
Section 1-1 (side view)

Fig. 3.19 Hydro-Brake flow regulator

(Permission of Hydro Research & Development)

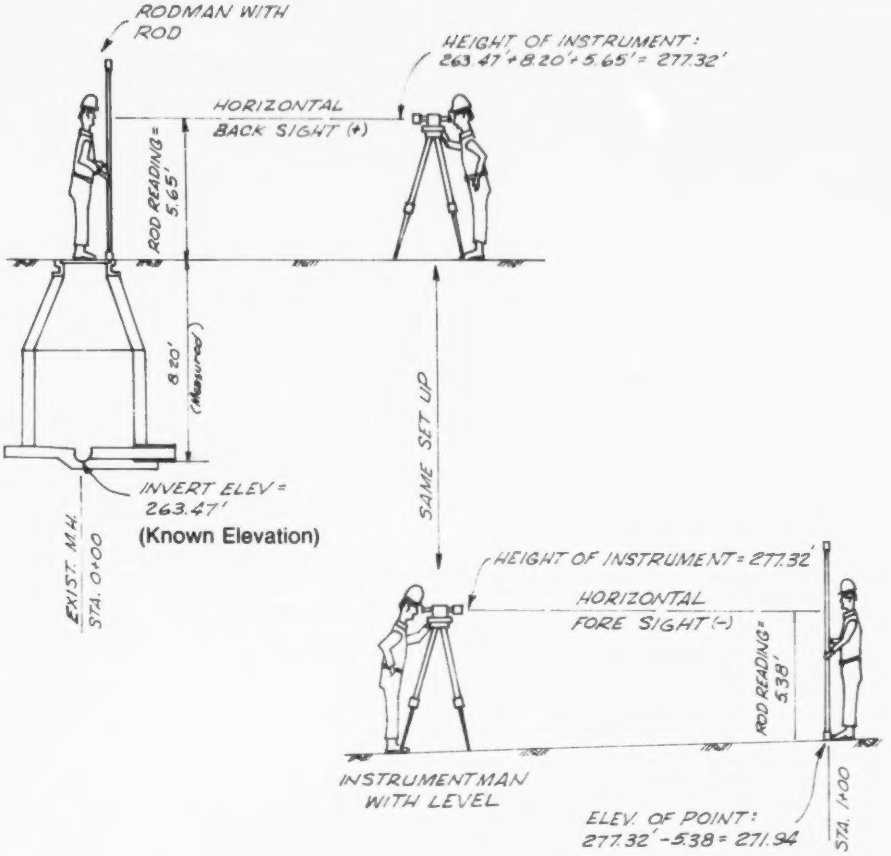


Fig. 3.20 Level survey

7. If you (the instrument surveyor) need to move the level due to (1) an obstruction in the line of sight, (2) the FS point being above the HI, or (3) the HI being above the upper end of the rod, establish a secondary bench mark (turning point) and carefully calculate its elevation. Move the level to a new location and determine the HI by back sighting on a turning point. For example, in the level survey made to develop the field notes shown in Figure 3.20, the nail designating 0 + 00 with a previously determined elevation of 271.63 was used as a turning point for the purpose of setting the level for observation of a storm sewer that had to be considered in design of the sanitary sewer. The height of the instrument was determined by back sighting on a rod held on the turning point and adding the reading to the elevation of the point (HI = TP + BS = 271.63 + 5.41 = 277.04). The elevation of the storm sewer manhole rim was determined by holding a rod on the rim and subtracting the fore sight rod reading from the HI (EL. MH Rim = HI - FS = 277.04 - 5.62 = 271.42).

8. The invert elevation of the storm sewer at the manhole was determined by using the surveyor's rod to measure the distance from the rim to the invert and then subtracting this distance from the rim elevation (EL. Invert = EL. Rim -Dip = 271.42 - 6.46 = 264.96).

As route and level surveys are conducted, field notes similar to those illustrated in Figure 3.21 are usually made by the person in charge (surveyor or crew leader).

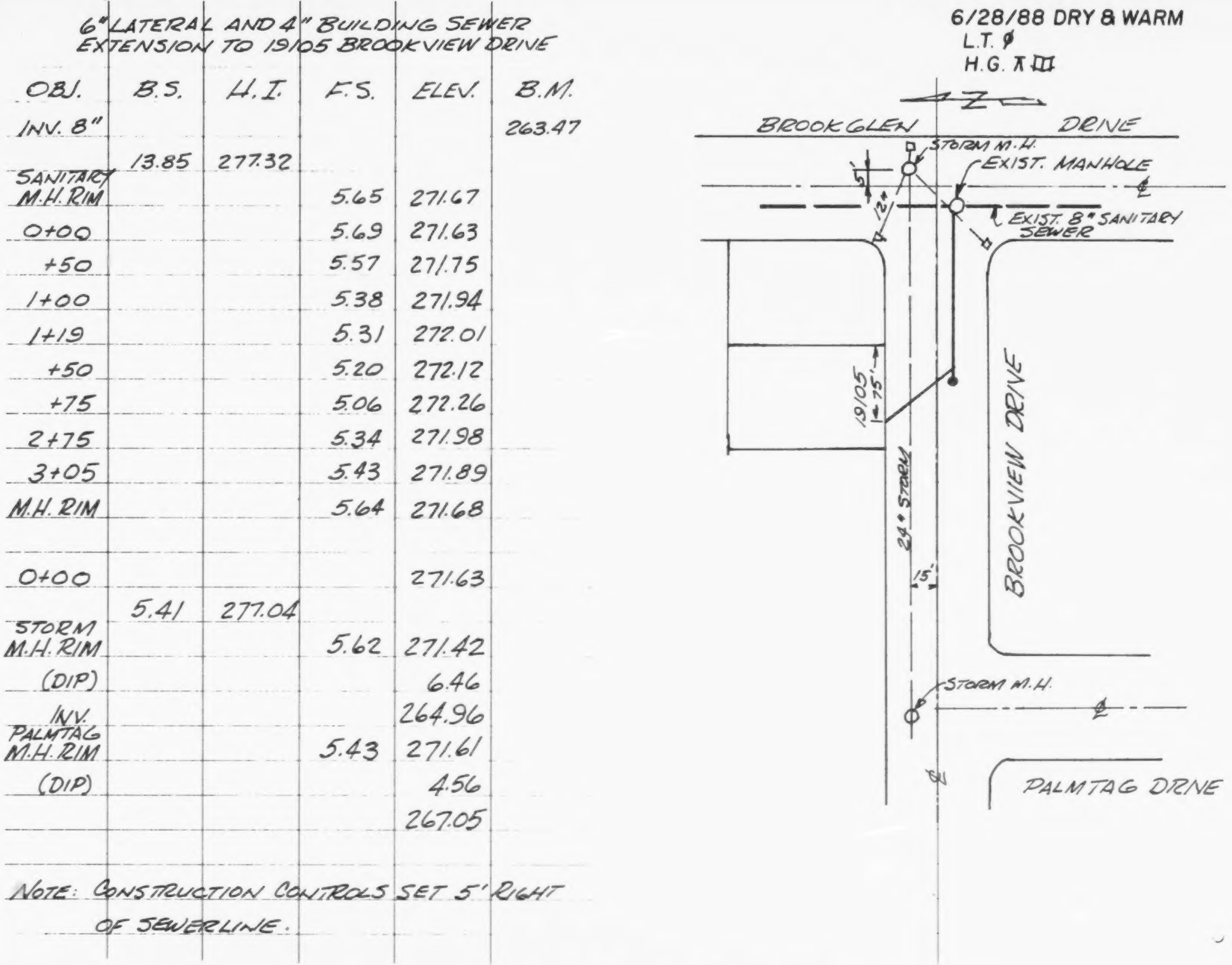
3.42 Slope and Size

The following factors are considered in determining the slope and size of a sewer line.

SLOPE OF SEWER should follow slope of land along the route of the sewer as closely as practical provided the slope is adequate to produce gravity flow and the minimum scouring velocity. Deviations from ground slope could cause the sewer to become too shallow for adequate cover on the pipe or too deep for safe and economical construction.

DESIGN FLOW is the estimated amount of wastewater to be conveyed by the sewer line being designed. Section 3.21 describes a method of determining the design flow of a collection system.

VELOCITY. The wastewater in a sewer line should move at a speed which will prevent the deposition and buildup of solids in the sewer; this is called a "scouring velocity." Experience has shown that wastewater velocities of two feet per second or greater will keep the solids usually contained in wastewater moving in a sewer line. A scouring or self-cleaning velocity may not be attainable during periods of minimum daily flows. However, a sewer should be designed to produce a scouring velocity during the average daily flow or, at the very least, during the maximum daily flow. Collection systems in flat regions with low flow velocities tend to have the solids settle out of the wastewater, thus causing sewer stoppages and the generation of toxic hydrogen sulfide gas. On the other hand, steep slopes on hilly terrain



6" LATERAL AND 4" BUILDING SEWER
EXTENSION TO 19105 BROOKVIEW DRIVE

6/28/88 DRY & WARM
L.T. ϕ
H.G. π III

OBJ.	B.S.	H.I.	F.S.	ELEV.	B.M.
INV. 8"					263.47
	13.85	277.32			
SANITARY M.H. RIM			5.65	271.67	
0+00			5.69	271.63	
+50			5.57	271.75	
1+00			5.38	271.94	
1+19			5.31	272.01	
+50			5.20	272.12	
+75			5.06	272.26	
2+75			5.34	271.98	
3+05			5.43	271.89	
M.H. RIM			5.64	271.68	
0+00				271.63	
	5.41	277.04			
STORM M.H. RIM			5.62	271.42	
(DIP)				6.46	
INV.				264.96	
PALMTAG M.H. RIM			5.43	271.61	
(DIP)				4.56	
				267.05	

NOTE: CONSTRUCTION CONTROLS SET 5' RIGHT OF SEWERLINE.

N
BROOKGLEN DRIVE
STORM M.H.
EXIST. MANHOLE
℄
5'
12"
EXIST. 8" SANITARY SEWER
19105
75'
24" STORM
15'
BROOKVIEW DRIVE
STORM M.H.
℄
℄
PALMTAG DRIVE

Fig. 3.21 Field notes

can produce high wastewater velocities in sewer lines. Velocities higher than ten feet per second can separate solids from the wastewater, cause excessive turbulence at junctions and erode the sewer line.

SIZE. A sewer line should be large enough for the use of cleaning equipment. A properly sized sewer line will be approximately one-half full when conveying the peak daily dry weather design flow and just filled when it is conveying the peak wet weather design flow. Designing for a half-full sewer line allows for a beneficial flow of air above the wastewater and allows for some error in determining the design flow. The flow of air helps prevent the buildup of toxic or explosive gases, an oxygen deficiency, moisture condensing on pipe walls and crown above the water line which can contribute to sulfide corrosion. Most wastewater agencies require at least a four-inch diameter residential building sewer and a six-inch diameter lateral and branch sewer. Many agencies require an eight-inch diameter lateral and branch sewer to facilitate maintenance and to convey unexpected wastewater flows. Commerical buildings require a six-inch or larger sewer line and industrial sewer lines are six-inches or larger and sized on the basis of expected flows.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 66.

3.4A Why are field surveys conducted?

3.4B What is the difference between a route survey and a level survey?

3.4C Why must a scouring velocity be maintained in a sewer line?

3.4D What will happen in a sewer if a scouring velocity is not maintained?

3.43 Velocity and Flow

The Manning Equation is commonly used by engineers to interrelate slope, quantity of wastewater (design flow) and velocity of flow in a sewer line. Although you will probably not be designing a complete system, this equation will be useful if you need to design an extension of an existing sewer or compare expected design velocities with actual velocities in sewers. The Manning Equation is as follows:

$$V = \frac{1.486}{n} R^{2/3} S^{1/2}$$

where V = velocity, ft/sec,

n = Manning's coefficient of pipe roughness,

R = hydraulic radius, ft

$$= \frac{\text{cross-sectional area of flow, sq ft}}{\text{wetted pipe perimeter, ft}}$$

and S = slope of sewer, ft/ft.

Knowing the available slope and desired depth of flow in a sewer line and assuming a coefficient of pipe roughness, the velocity of flow can be calculated. Then, knowing the velocity and the cross-sectional area of flow, the flow rate can be calculated using the formula:

$$Q = AV$$

where Q = flow, cubic feet per second,

A = Area, square feet, and

V = velocity, ft/sec.

EXAMPLE 6

The slope of an 8-inch diameter sewer is 0.004 ft per ft, the pipe is flowing one-half full and the coefficient of pipe roughness is assumed to be 0.013. Determine the velocity and quantity (flow rate) of wastewater conveyed by the sewer.

KNOWN		UNKNOWN
Slope, S, ft/t	= 0.004 ft/ft	Velocity, V, ft/sec
Diameter, D, in	= 8 in	Quantity, Q, MGD
Roughness, n	= 0.013	

1. Calculate the cross-sectional area of the pipe when it is flowing half full (refer to Example 2, page 39).

$$\frac{\text{depth}}{\text{Diameter}} = \frac{(1/2)(8\text{ in})}{8\text{ in}}$$

$$= \frac{4\text{ in}}{8\text{ in}}$$

$$= 0.50$$

From Table 3.4, if d/D = 0.50, factor = 0.3927.

2. Calculate the pipe cross-sectional flow area.

$$\text{Pipe flow area, sq ft} = \frac{(\text{Factor})(\text{Diameter, in})^2}{144\text{ sq in/sq ft}}$$

$$= \frac{(0.3927)(8\text{ in})^2}{144\text{ sq in/sq ft}}$$

$$= 0.175\text{ sq ft}$$

---

[11] *Values for pipe roughness coefficients may be found in hydraulics textbooks which contain values for Manning's n. The value of n increases with the roughness of the pipe which depends on the pipe material and age of the pipe.*

3. Calculate the WETTED PERIMETER[12] for a pipe flowing half full.

$$\text{Wetted perimeter, ft} = \frac{(1/2)(3.14)(\text{Diameter, in})}{12\text{ in/ft}}$$

$$= \frac{(0.5)(3.14)(8\text{ in})}{12\text{ in/ft}}$$

$$= 1.05\text{ ft}$$

4. Calculate the hydraulic radius, R, in feet.

$$\text{Hydraulic radius, R, ft} = \frac{\text{Flow area, A, sq ft}}{\text{Wetted perimeter, P, ft}}$$

$$= \frac{0.175\text{ sq ft}}{1.05\text{ ft}}$$

$$= 0.167\text{ ft}$$

5. Calculate the flow velocity in feet per second.

$$\text{Velocity, V, ft/sec} = \frac{1.486}{n}\ R^{2/3}S^{1/2}$$

$$= \frac{1.486}{0.013}\ (0.167\text{ ft})^{2/3}(0.004)^{1/2}$$

$$= (114.3)(0.303)(0.063)$$

$$= 2.19\text{ ft/sec}$$

6. Calculate the quantity of flow in cubic feet per second.

$$\text{Quantity, Q, CFS} = (\text{Area, sq ft})(\text{Velocity, ft/sec})$$

$$= (0.175\text{ sq ft})(2.19\text{ ft/sec})$$

$$= 0.383\text{ cu ft/sec}$$

7. Convert the quantity of flow from cubic feet per second to million gallons per day, MGD.

$$\text{Quantity, Q, MGD} = \frac{(\text{Quantity, Q, cu ft/sec})(7.48\text{ gal/cu ft})(60\text{ sec/min})(60\text{ min/hr})(24\text{ hr/day})}{1{,}000{,}000/\text{M}}$$

$$= \frac{\text{Quantity, Q, cu ft/sec}}{1.55\text{ cu ft/sec/MGD}}$$

$$= \frac{0.38\text{ cu ft/sec}}{1.55\text{ cu ft/sec/MGD}}$$

$$= 0.245\text{ MGD}$$

The 8-inch diameter pipe would be acceptable for the proposed sewer if the peak daily dry weather design flow is approximately 0.245 MGD and the peak wet weather design flow is approximately 0.490 MGD. If not, either the design slope or pipe diameter or both would have to be increased until the appropriate combination of sewer line slope and diameter would produce the desired capacity and velocity.

3.44 Location and Alignment

Lateral, main and trunk sewers are usually constructed at or near the center of public streets to equalize the length of building sewers and to provide convenient access to the sewer line manholes. In extremely wide and heavily traveled streets, lateral sewers are sometimes placed on each side of the street to reduce the length of building sewers and to lessen interference with traffic when the sewer is being maintained. Sewer lines are usually separated from water mains by a distance prescribed by the appropriate health agency. Sewers are sometimes placed in easements when the topography of the land or street layout requires their use. Use of easements should be minimized since sewers in easements are more difficult to gain access to and to maintain than sewers in streets.

With the greater use of curved streets today and the development of sewer cleaning equipment that is more versatile, sewers are sometimes constructed along curved paths. The radius of a curved sewer will be determined by the radius of the street in which the sewer is being constructed, allowable deflection in the sewer pipe joints and, of major importance, the effect of radius upon cleaning procedures. Some state and local regulatory agencies prohibit the use of curved sewers because of maintenance problems. For the efficient use of modern sewer cleaning equipment, the radius of curvature must be greater than 200 feet. Also, most pipe manufacturers will specify the maximum allowable deflection (departure from a straight line) in their pipe joints; this amount is usually sufficient for modern sewer cleaning equipment.

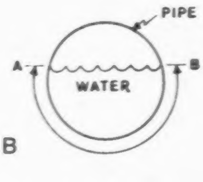
3.45 Depth

The depth of lateral and main sewers should generally be approximately six-feet deep. This depth will allow connecting building sewers to cross under most underground utilities and will serve the drainage systems of most buildings without basements. If most buildings in a collection system's service area include basements, the lateral and main sewers should be deep enough to serve drainage systems in the basements by gravity. The depth of trunk and interceptor sewers will depend to a great extent upon the depth of connecting main sewers.

The depth and width of a trench, backfill material and method of compaction determine the load placed on the sewer pipe (Figure 3.22). The amount of support provided the sewer pipe by the sides of the trench decreases as the width of the trench increases. The width of a sewer trench (controlled by the diameter of the pipe, clearance for pipe laying, soil stability for safety during excavation, and the excavation procedures) should be kept to a minimum.

---

[12] *Wetted Perimeter. The length of the wetted portion of a pipe covered by flowing wastewater.*



Wetted Perimeter = Distance from A to B

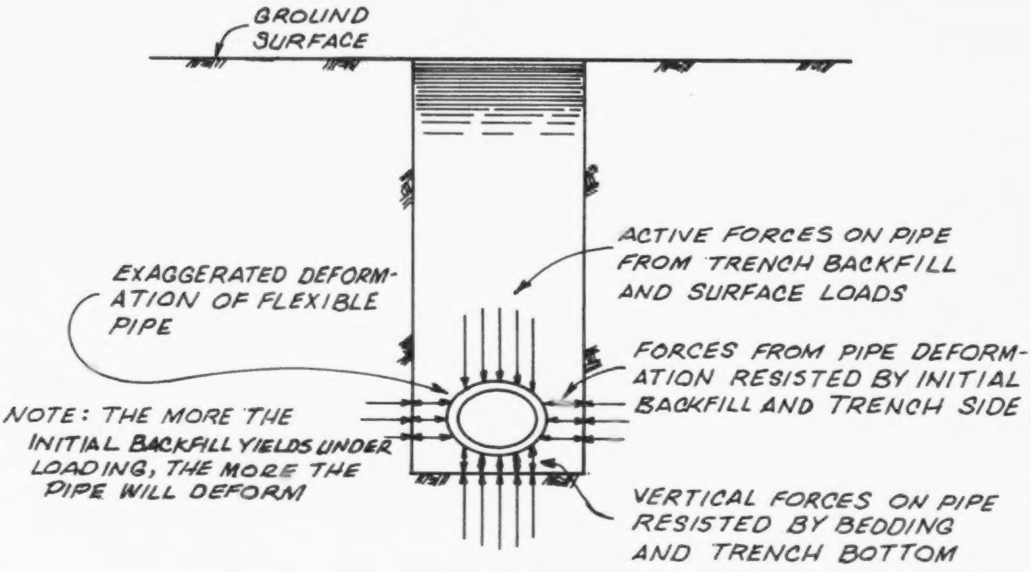

GROUND SURFACE
ACTIVE FORCES ON PIPE FROM TRENCH BACKFILL AND SURFACE LOADS
EXAGGERATED DEFORMATION OF FLEXIBLE PIPE
FORCES FROM PIPE DEFORMATION RESISTED BY INITIAL BACKFILL AND TRENCH SIDE
NOTE: THE MORE THE INITIAL BACKFILL YIELDS UNDER LOADING, THE MORE THE PIPE WILL DEFORM
VERTICAL FORCES ON PIPE RESISTED BY BEDDING AND TRENCH BOTTOM

Fig. 3.22 Pipe loading

Most sewer pipe manufacturers will provide information on the allowable loading on their pipe based on depth, trench width and bedding conditions.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 66.

3.4E If a 10-inch diameter sewer on a 0.005 ft/ft slope will not carry the peak wet weather design flow, what could be done to provide adequate capacity?

3.4F Why are sewers usually not placed in easements?

3.4G What factors control the width of a sewer trench?

3.46 Pipe Materials

Construction materials for sewers are selected for their resistance to deterioration by the wastewaters they convey, strength to withstand earth and surface loads, resistance to root intrusion, their ability to minimize infiltration and exfiltration, and the cost of the materials and their installation. Care must be taken in the selection of materials since sewers are expected to have an economical life of at least 30 years and most are in service for a much longer period.

Pipe for construction of sanitary sewers is manufactured from several types of material producing either flexible or rigid pipe with specific characteristics that will perform satisfactorily in a particular situation. A flexible pipe will bend or bulge from its usual shape when subjected to a load without being adequately supported. However, it will not crack under most loads and will return nearly to its original shape when a load is removed. A rigid pipe will require less support; however, it will crack when the combination of a load on the pipe and its support causes a stress that exceeds the strength of the pipe. It will not return to its original shape when the load is removed. Most of the commonly used sanitary sewer materials are described in the following subsections.

3.460 Acrylonitrile Butadiene Styrene Pipe (ABSP)

This flexible plastic pipe is resistant to abrasion and virtually unaffected by water, inorganic salts, alkalies and acids usually found in wastewater. However, this pipe will be softened and eroded by wastewater containing petroleum products which are normally prohibited from being discharged into a sewer. Pipes are joined in the field by applying solvent cement to (welded) bell and spigot joints. ABSP cannot withstand heavy external (outside) loads and if not properly placed and backfilled, will deflect into an oval shape which make routine maintenance by certain cleaning tools impossible.

3.461 Asbestos Cement Pipe (ACP)

This pipe is rigid, resistant to abrasion, watertight and resistant to deterioration by most types of wastewaters. The pipe can be corroded by the acid formed from hydrogen sulfide gas, and the pipe should not be used where the release of hydrogen sulfide gas can occur. Joints are made of sleeve and rubber gasket couplings.

3.462 Cast and Ductile Iron Pipe (CIP and DIP)

The pipe is rigid and very resistant to crushing by surface and earth loads. Pipe is costly, but should be used for creek crossings and bridge crossings, or where trenches are shallow and under heavy traffic loads. Joints are either rubber-gasketed mechanical or push-on types.

3.463 Corrugated Metal Pipe (CMP)

CMP is a flexible pipe with bitumastic coating that is resistant to most chemicals found in wastewater. Special rubber gasketed corrugated bands with bolt tighteners are used with asphalt smooth-lined pipe. In the past some CMP installations have had problems with leaking joints. Also the bitumastic coating has broken loose or been eroded away by high flows. Problems develop at the treatment plant when the coating reaches the bar screens or settles out in the sedimentation tanks.

3.464 Polyvinylchloride Pipe (PVCP)

This pipe is flexible and resistant to most chemicals found in wastewaters. Joints are commonly made with a rubber gasket and a factory-formed bell and spigot or a welded coupling joint can be used. PVC pipe has experienced problems with heavy external loads.

3.465 Reinforced and Nonreinforced Concrete Pipe (RCP and CP)

Concrete pipe is rigid and can be corroded by acids in wastewater or acid formed from hydrogen sulfide. Sometimes a coal tar epoxy compound coating or a plastic sheet lining can be used to line the pipe to retard the corrosive action. Rubber-gasketed bell and spigot joints commonly are used for sanitary sewer installations and may leak if not properly installed.

3.466 Reinforced Plastic Mortar (RPMP) and Fiberglass Reinforced Pipe (FRP)

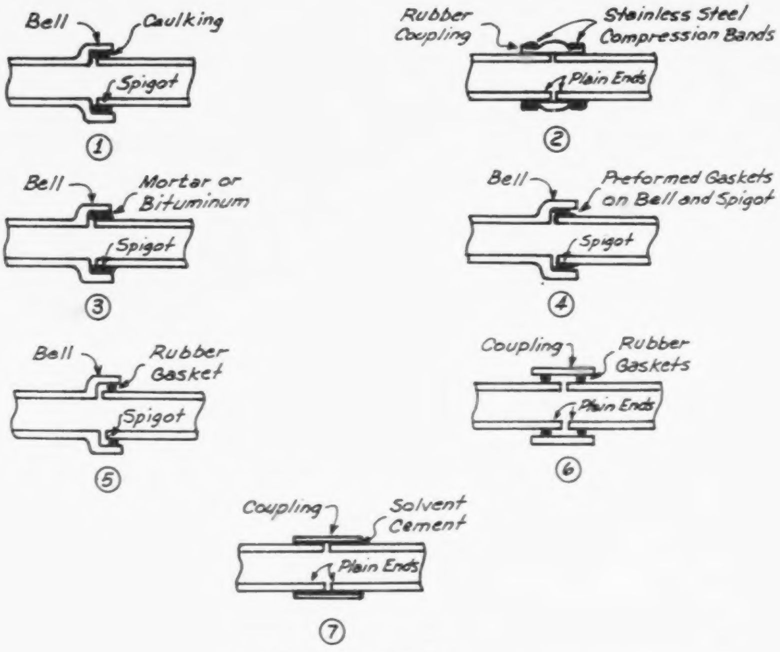
These pipes are flexible and resistant to corrosion by most chemicals found in wastewaters and acids formed in sewers; however, there is some evidence that these pipes are damaged by hydrogen sulfide. Joints are made with a rubber-gasketed bell and spigot. The manufacturer's installation instructions must be carefully followed since experience has shown this pipe to be subject to failure within several years of construction due to earth loadings not anticipated when the pipe installation was designed.

3.467 Vitrified Clay Pipe (VCP)

The pipe is rigid and is resistant to internal and external attack from acids, alkalies, gases, solvents, and other materials that are carried in wastewater. Joints usually consist of bells and spigots with factory-formed compression joints (liners of resilient-type plastic), or with rubber couplings held in place by stainless steel bands. Older pipes have mortar joints.

3.468 Pipe Joints

Pipe joints are a critical factor in every sewer. Poor joints can lead to problems caused by roots, infiltration and exfiltration. When reviewing the type of joint, consider the location of the sewer and loads that will be placed on the joint (traffic, settling or other potential types of earth movement). Figure 3.23 summarizes the common types of joints and the types of pipes with which they are used.



TYPE OF JOINTS

Joint No.	Joint Description	Joint Used with:							
		ABSP	ACP	CIP	PVCP	RCP	CP	RPMP	VCP
1	Caulked Bell & Spigot			✓					
2	Coupling for Plain End Pipe			✓					✓
3	Mortar/Bituminous Filled Bell & Spigot					✓	✓		✓
4	Polyvinyl Chloride/Polyurethane Preformed Gaskets in Ball & Spigot								✓
5	Rubber Gasketed Ball & Spigot			✓	✓	✓		✓	✓
6	Rubber Gasketed Coupling		✓						
7	Solvent Cemented Coupling	✓							

Fig. 3.23 Common types of joints for sewer pipe

3.47 Manhole Materials

Manhole bases are generally made of poured-in-place unreinforced concrete with wastewater channels formed by hand before the concrete hardens. Manhole barrels are usually made of pre-cast concrete sections with cement mortar or bitumastic joints. Manholes in older collection systems may have been made with clay bricks and cement mortar joints. Some manhole barrels are now being made with fiberglass for use in areas with high groundwater and corrosive material in the wastewater conveyed. Manhole frame and covers are made of cast iron with the mating surface between the frame and cover machined to ensure a firm seating. Manhole steps should be made of wrought iron or reinforced plastic to resist corrosion. In some jurisdictions steps are prohibited and ladders are used to eliminate the hazard of corroded steps.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 66.

3.4H What is the difference between flexible and rigid pipe?

3.4I List the most commonly used sanitary sewer pipe materials.

3.4J List the problems that can be caused by poor sewer pipe joints.

3.4K Why are some manhole barrels made with fiberglass?

3.5 PLAN AND PROFILE

A civil engineer will use the field data described in Section 3.41 and the design criteria described in Sections 3.42 through 3.47 to prepare plans and specifications for the construction of a wastewater collection system.

A typical plan (top view) and profile (side view) for a short sewer extension based on the field notes illustrated in Figure 3.21 is illustrated in Figure 3.24.

3.6 DESIGN REVIEW

Wastewater collection system operators should request the opportunity to review the design of collection systems that they will be responsible for maintaining after construction. In order to make an effective review an operator must be familiar with the elements of design that can create problems during the life of a collection system. The following sections give some suggestions for the review of plans and profiles for construction of a collection system.

3.60 Office Study

When you receive a set of plans and profiles for review, look them over for an overview of how the system is to work. Then make a detailed review by asking yourself how the design may be improved for the elimination of future maintenance problems. Make a list of items that are not clear to you and ask the designer for a clarification. Some items that you should consider in your review are set forth in Section 3.62.

3.61 Field Investigations

Now that you are familiar with the plans and profiles for a collection system and have developed some ideas and questions concerning the effect of the design on maintenance, you are prepared for a field investigation. Envision the maintenance of the sewer lines and appurtenances as planned and ask yourself how the actual field conditions will influence maintenance.

3.62 Design Items Influencing Maintenance

During both the office and field review of plans and profiles for a wastewater collection system, ask yourself the following questions concerning the design:

1. Is the route or alignment satisfactory?
2. Could there be a better route?
   a. Consider the effect of pipe diameters and depth of excavation on future maintenance.
   b. Think about maintenance equipment access.
3. Is there sufficient overhead clearance for maintenance and repair equipment?
4. How could repairs be made in case of failures?
   a. Availability of large diameter pipe?
   b. Depth of excavation?
   c. Shoring requirements?
5. Can the system be easily and properly operated and maintained?
6. Will there be any industrial waste dischargers? If so, what will they discharge and will the discharge cause any problems? How can these problems be controlled?
7. Where can vehicles be parked when operators and equipment require access to a manhole?
8. Is traffic a problem around or near a manhole and if so can it be relocated to minimize the problem? Will night work be necessary?
9. Can the atmosphere in the manhole be tested safely for oxygen deficiency, explosive gases and toxic gases? Can large ventilation blowers be used?
10. Can an operator reach the bottom of the manhole with a ladder if steps are not provided?
11. If there are steps in the manhole wall for access, will they be damaged by corrosion and become unsafe?
12. Is the shelf in the bottom of the manhole properly sloped? If the shelf is too flat, it will get dirty; if the shelf is too steep, it can be a hazard to operators.
13. Are the channels properly shaped to provide smooth flow through a manhole to minimize splashing and turbulence that can cause the release of toxic, odorous, and corrosive hydrogen sulfide?
14. Are the channels at least as large as the pipe so maintenance equipment and plugs can be fitted or inserted into the pipes?
15. Can the available sewer maintenance equipment be effective between the manholes or is the distance too great?
16. Is the manhole opening large enough to allow access for tools and equipment used to maintain a large sewer line? Is the opening sufficient to handle equipment and personnel during routine maintenance or inspection?
17. Does the area flood? How often? Can flows be diverted? Stored? How? For how long? What tools, equipment and procedures are needed?

In addition to the above questions, use your experience to raise other questions on how the design of a collection system can affect your future operation and maintenance of the system and making repairs in emergency situations.

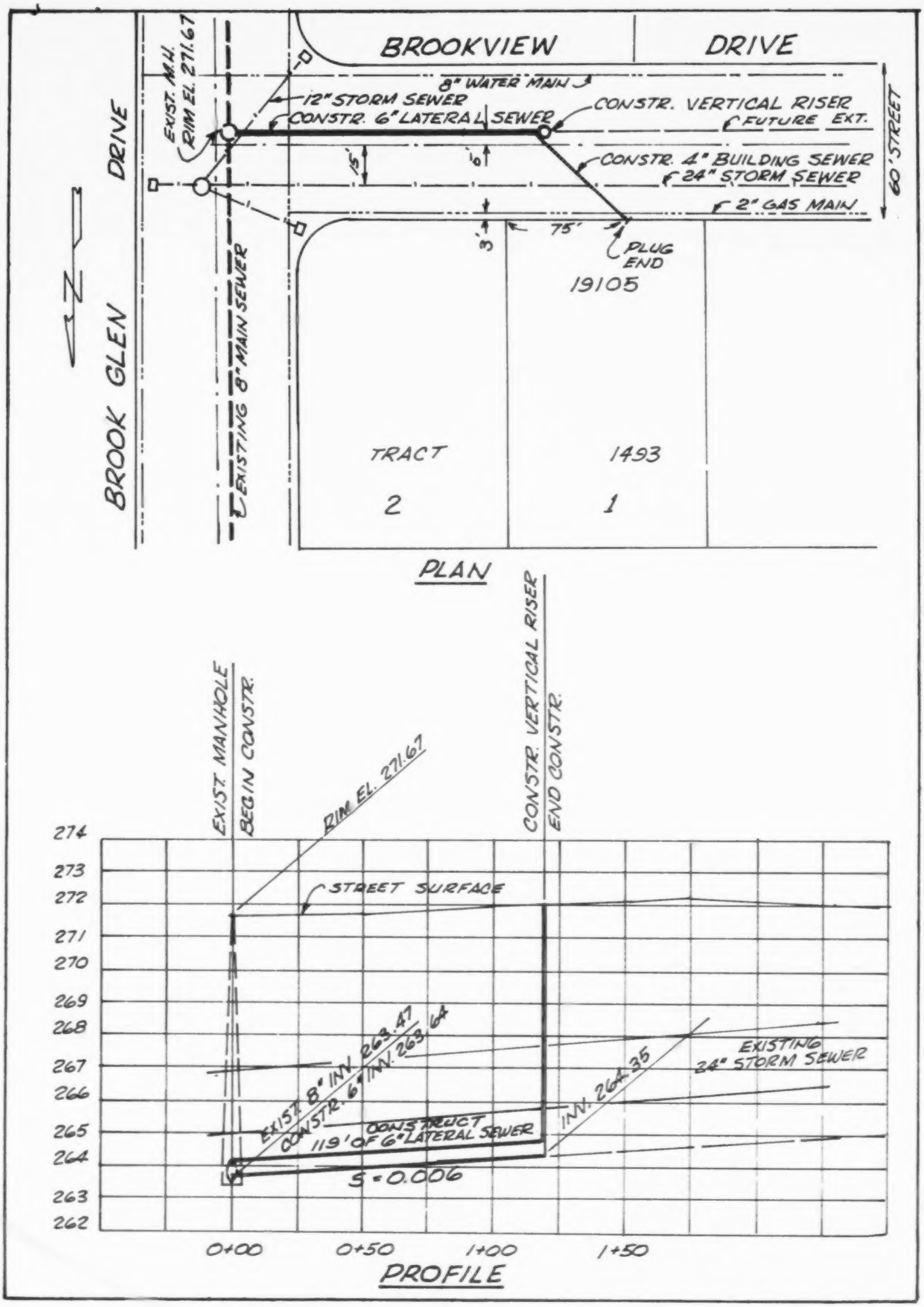

BROOKVIEW
DRIVE
8" WATER MAIN
12" STORM SEWER
CONSTR. 6" LATERAL SEWER
CONSTR. VERTICAL RISER
FUTURE EXT.
CONSTR. 4" BUILDING SEWER
24" STORM SEWER
2" GAS MAIN
60' STREET
EXIST. M.H. RIM EL. 271.67
EXISTING 8" MAIN SEWER
BROOK GLEN
DRIVE
N
15'
6'
3'
75'
PLUG END
19105
TRACT
1493
2
1
PLAN
EXIST. MANHOLE
BEGIN CONSTR.
CONSTR. VERTICAL RISER
END CONSTR.
RIM EL. 271.67
STREET SURFACE
EXIST. 8" INV. 263.47
CONSTR. 6" INV. 263.64
CONSTRUCT 119' OF 6" LATERAL SEWER
S = 0.006
INV. 264.35
EXISTING 24" STORM SEWER
274
273
272
271
270
269
268
267
266
265
264
263
262
0+00
0+50
1+00
1+50
PROFILE

Fig. 3.24 Plan and profile

3.63 Communication

Your questions and ideas concerning the improvement of the design of a collection system should be given to the designer in a written and understandable form with an offer to meet to discuss them. The designer should be capable of explaining and justifying a design in terms of economics and installation. You should be able to justify your concerns on the basis of operation and maintenance requirements.

3.64 Construction, Testing and Inspection

Designers must consider how the wastewater collection facilities they design will be constructed. Some facilities have been properly designed, but have not functioned as intended due to poor or improper construction materials and techniques. Good construction, inspection and testing procedures are very important in order to eliminate operation and maintenance problems that could develop from poor construction practices. Whenever problems (stoppages, failures or odors) develop in your collection system, try to identify the cause so it can be corrected now and in the future design of new systems. Did the problem start with the design, construction, or inspection of the facility; or was it caused by a waste discharger, by aging of the isystem, or by your maintenance and repair program? Whatever the cause, identify it and try to correct it.

The Supplement of this chapter provides details regarding the construction, inspection and testing of wastewater collection systems. Knowledge of this material will help you communicate with design engineers and also help you identify the causes of problems in your collection system. If your job today is not directly related to construction or construction inspection and testing, you may wish to skip the Supplement at this time, work the Objective Test, and go on to Chapter 4, "Safe Procedures."

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 67.

3.5A What is the plan and profile of a sewer?

3.6A When reviewing plans for a new sewer, where could traffic be a problem?

3.6B Why is the slope of the shelf in a manhole important?

DISCUSSION AND REVIEW QUESTIONS

Chapter 3. WASTEWATER COLLECTION SYSTEMS

Answer these discussion and review questions before continuing. The purpose of these questions is to indicate to you how well you understand the material in the lesson. Write the answers to these questions in your notebook before continuing.

1. Why should collection system operators know how engineers design wastewater collection systems?
2. How does inflow and infiltration get into wastewater collection systems?
3. Why are lift stations installed?
4. Why are low pressure collection systems sometimes used as an alternative to gravity collection systems?
5. Why are vacuum collection systems sometimes used as an alternative to gravity collection systems?
6. Why are manholes installed in sewer lines?
7. What is the purpose of interconnector sewers?
8. How can collection system operators communicate with engineers regarding wastewater collection system design?
9. Why should the slope of sewers follow the slope of the land?
10. Why are lateral, main and trunk sewers usually constructed at or near the center of a street?
11. What factors need to be considered in the selection of materials for sewer construction?
12. Why are good construction, inspection and testing procedures very important?
13. When is a wastewater pump used in a collection system?
14. How would you measure the flow velocity in a sewer?
15. How can wastewater collection system operators (you) help engineers design better systems?

SUGGESTED ANSWERS

Chapter 3. WASTEWATER COLLECTION SYSTEMS

Answers to questions on page 36.

3.0A Collection system operators should understand how the systems they are responsible for operating and maintaining were designed and constructed so they can determine the correct action to take when the system fails to operate properly. Also they will be able to discuss design, construction and inspection with engineers.

3.1A The purpose of a wastewater collection system is to collect and convey the wastewater from a community's homes and industries at an appropriate velocity to a wastewater treatment plant.

3.1B In areas where the topography is unfavorable for a gravity wastewater collection system, a pressure or vacuum collection system may be used.

Answers to questions on page 42.

3.2A Sources or types of wastewater conveyed by wastewater collection systems include wastewater from domestic, commercial and industrial sources, as well as groundwater infiltration and surface water inflows produced in the service area.

3.2B The peak flow from a service area is estimated on the basis of maximum population and full commercial and industrial development of the area, with additional allowances for infiltration and inflow.

3.2C The flow velocity in a sewer main can be measured using either dyes or floats.

Answers to questions on page 44.

3.3A The parts or components of a gravity wastewater collection system include building sewers, lateral and branch sewers, main sewers, trunk sewers, intercepting sewers, manholes, and lift stations.

3.3B The principal components of a low pressure collection system include gravity sewers, holding tanks, grinder pumps and pressure mains.

3.3C The principal components of a vacuum collection system include gravity sewers, holding tanks, vacuum valves, vacuum mains and vacuum pumps.

Answers to questions on page 52.

3.3D Backflow preventers are used to stop the accidental backflow or reverse flow of wastewater into buildings from the sewer.

3.3E The two major types of wastewater backflow preventers are the (1) overflow type and (2) backwater check valve.

3.3F Inverted siphons are sewer lines depressed under obstructions to the normal gradient of the sewer line such as water courses and depressed roadways.

3.3G Flow regulators in wastewater collection systems are used to divert the flow of wastewater from one sewer line to another for the efficient use of the system and to prevent overloading one portion of the system. They are also used when performing maintenance on a main line or intercepting sewer.

Answers to questions on page 59.

3.4A Field surveys are conducted to determine the location of the physical features and the elevation of the ground surface along the planned route of the sewer lines in the collection system. Field surveys include both route and level surveys.

3.4B Route surveys determine the location of physical features that influence the horizontal location of a sewer line. Level surveys determine elevations of the ground surface along the route of the sewer line, buildings to be served, and the elevation of underground obstructions and pipelines.

3.4C A scouring velocity must be achieved during some time of a day in a sewer to prevent the deposition and buildup of solids in a sewer.

3.4D If a scouring velocity is not maintained in a sewer, the solids will settle out. These solids will cause sewer stoppages and the generation of hydrogen sulfide gas which is corrosive, toxic and odorous.

Answers to questions on page 61.

3.4E If a 10-inch diameter sewer on a 0.005 ft/ft slope will not carry the peak wet weather design flow, either the diameter or the slope or both could be increased to provide sufficient capacity.

3.4F Sewers are usually not placed in easements because they are more difficult to gain access and to maintain than sewers in streets.

3.4G The width of a sewer trench is controlled by the diameter of the sewer pipe, clearance for pipe laying, soil stability for safety during excavation and the excavation procedures.

Answers to questions on page 63.

3.4H A flexible pipe will bend or bulge from its usual shape when subjected to a load without being adequately supported. However, it will not crack under most loads and will return nearly to its original shape when a load is removed. A rigid pipe will require less support; however, it will crack when the combination of a load on the pipe and its support causes a stress exceeding the strength of the pipe. It will not return to its original shape when the load is removed.

3.4I The most commonly used sanitary sewer pipe materials include acrylonitrile butadiene styrene pipe (APSP or plastic), asbestos cement pipe (ACP), cast and ductile iron pipe (CIP and DIP), corrugated metal pipe (CMP), polyvinylchloride pipe (PVCP), reinforced and nonreinforced concrete pipe (RCP and CP), reinforced plastic mortar pipe (RPMP), fiberglass reinforced pipe (FRP) and vitrified clay pipe (VCP).

3.4J Poor sewer pipe joints can lead to problems caused by roots, infiltration and exfiltration.

3.4K Some manhole barrels are made with fiberglass for use in areas with high groundwater and corrosive material in the wastewater conveyed.

Answers to questions on page 65.

3.5A The plan view is the top view of a sewer and shows the pipe, manholes and street. The profile is the side view of a sewer and shows the pipe, manholes, invert elevations, street surface and underground pipes such as storm sewers, gas mains, water mains and electrical cables.

3.6A When reviewing plans for a new sewer, traffic could be a problem wherever crews must work, such as around manholes. Also consider where vehicles will be parked when operators and equipment require access to a manhole.

3.6B The slope of the shelf of a manhole is important because if the slope is too flat, the shelf will get dirty; and, if too steep, the shelf can be a slippery hazard to operators.

OBJECTIVE TEST

Chapter 3. WASTEWATER COLLECTION SYSTEMS

Please mark correct answers on answer sheet as directed at the end of Chapter 1. There may be more than one correct answer to each multiple-choice question.

TRUE-FALSE

1. Persons responsible for the operation and maintenance of wastewater collection systems are usually responsible for the design, construction and inspection of these systems.
   1. True
   2. False

2. The "peaking factors" for maximum to average daily flows increase as the population increases.
   1. True
   2. False

3. Collection system operators need to be familiar with the elements of a wastewater collection system design that have an influence on the operation and maintenance of the constructed system.
   1. True
   2. False

4. A knowledge of the wastewater flow fluctuations in a collection system can be useful in planning a wastewater collection system maintenance program.
   1. True
   2. False

5. Hydraulic formulas which give the theoretical velocity in a sewer should be used to estimate the actual flow velocity in a sewer.
   1. True
   2. False

MULTIPLE CHOICE

6. Collection system operators need to know how engineers design collection systems so they can
   1. Actually design large, permanent collection systems.
   2. Discuss design with engineers.
   3. Determine corrective action during emergencies.
   4. Do a better job.
   5. Perform design calculations done by engineers.

7. The amount of groundwater infiltration into a wastewater collection system depends on
   1. Age of system.
   2. Condition of system.
   3. Peaking factors.
   4. Population served.
   5. Portion of system submerged in groundwater.

8. Knowledge of daily fluctuations in a collection system's wastewater flow is useful in planning
   1. Cleaning with bucket equipment.
   2. Hydraulic cleaning operations.
   3. Irrigation watering programs.
   4. Materials used in sewer lines.
   5. Sewer maintenance programs.

9. Lateral and branch sewers
   1. Are located at the upper ends of the collection system.
   2. Are the main "arteries" of a wastewater collection system.
   3. May be located in easements.
   4. Receive wastewater from trunk sewers.
   5. Run between the drainage system of a building and the street sewer.

10. Grinder pumps in low pressure collection systems
    1. Are the "arteries" of the low pressure system.
    2. Grind the solids in the wastewater.
    3. Pressurize the wastewater for conveyance.
    4. Pump wastewater to a holding tank.
    5. Serve as a reservoir for pressurized wastewater.

11. Vacuum valves in vacuum collection systems
    1. Are programmed to introduce an appropriate amount of wastewater into the main collectors.
    2. Are the "arteries" of a vacuum collection system.
    3. Maintain the required vacuum level in the main.
    4. Seal the line leading to the main collector.
    5. Serve as a holding reservoir.

12. Manholes are installed in sewer lines for the purpose of placing ________ into the sewers.
    1. Backflow devices
    2. Equipment
    3. Lamp holes
    4. Materials
    5. Persons

13. Manholes are used for
    1. Access to sewer lines.
    2. Inspection.
    3. Maintenance.
    4. Prevention of inflow.
    5. Removal of solids from cleaning.

14. Manholes are placed at changes in sewer line
    1. Direction.
    2. Elevation.
    3. Materials.
    4. Pipe size.
    5. Slope.

15. When reviewing plans and specifications for proposed wastewater collection systems, operators should look for
    1. Access to manholes.
    2. Cost of construction.
    3. Ease of system O & M.
    4. Locations of overhead power lines.
    5. Strength of pipe.

16. When solids settle out in sewers, they can produce
    1. Corrosive conditions.
    2. Odors.
    3. Scouring velocities.
    4. Stoppages.
    5. Toxic hydrogen sulfide gas.

17. Experience has shown that the minimum scouring velocity in a sewer should be greater than
    1. 2 ft/sec.
    2. 3 ft/sec.
    3. 4 ft/sec.
    4. 6 ft/sec.
    5. 10 ft/sec.

18. Designing a sewer line to flow half full when conveying peak daily dry weather design flow allows for
    1. Accumulation of sewer gases.
    2. Beneficial flow of air above wastewater.
    3. Space to convey peak wet weather design flow.
    4. Solids to settle out.
    5. Some error in determining the design flow.

19. Construction materials for sewers are selected on the basis of their ability to
    1. Convey design flows.
    2. Corrode when in contact with wastewater.
    3. Minimize infiltration and exfiltration.
    4. Resist root intrusion.
    5. Withstand earth and surface loads.

20. Poor sewer joints can lead to problems caused by
    1. Corrosion.
    2. Infiltration and exfiltration.
    3. Roots.
    4. Solids settling out.
    5. Toxic hydrogen sulfide gas.

21. When reviewing the plans and specifications for a new gravity sewer and lift station, what items should be considered?
    1. How to clean the sewer
    2. How to clear stoppages
    3. How to control hydrogen sulfide
    4. How to control odors
    5. How to handle flows when lift station pumps fail

22. What questions should be asked and answered during a review of plans and specifications and a field investigation of a new intercepting sewer?
    1. Are easements large enough?
    2. Can the system be easily and properly operated and maintained?
    3. How can repairs be made in case of failures?
    4. Is the route or alignment satisfactory?
    5. Is there sufficient overhead clearance?

23. Wastewater should flow at a scouring velocity so that
    1. Flow velocities can be estimated between manholes.
    2. Roots won't grow in sewers.
    3. Sewer pipes won't become eroded on the bottom.
    4. Solids won't build up in a sewer and reduce flow capacity.
    5. Solids won't settle out on the bottom of a sewer.

24. Estimate the flow in cubic feet per second in a ten-inch diameter sewer flowing full. A dye test indicates that the velocity is 2.4 feet per second. Select the closest answer.
    1. 0.13 cfs
    2. 0.23 cfs
    3. 1.31 cfs
    4. 1.67 cfs
    5. 1.89 cfs

END OF OBJECTIVE TEST

SUPPLEMENT

Chapter 3. WASTEWATER COLLECTION SYSTEMS

3.7 Construction 70

- 3.70 Excavation and Shoring 71
- 3.71 Controls 78
- 3.72 Sewer Pipe Bedding and Initial Backfill 82
- 3.73 Pipe Laying 85
- 3.74 Sewer Appurtenances 87
- 3.75 Sewer Trench Backfill and Compaction 88

3.8 Sewer Construction Inspection and Testing 92

- 3.80 Need for Sewer Construction Inspection and Testing 92
- 3.81 Duties of An Inspector 92
- 3.82 Qualifications of An Inspector 92
- 3.83 Inspection and Testing of Construction Materials 92
- 3.84 Inspection of Construction Procedures 93
- 3.85 Air Testing 94
- 3.86 Water Testing 101
- 3.87 Mandrel Test 102
- 3.88 Final Inspection 103
- 3.89 Construction Records 104

3.9 Additional Reading 108

SUPPLEMENT

Chapter 3. WASTEWATER COLLECTION SYSTEMS

OBJECTIVES

After completion of this Chapter 3 Supplement you should be able to:

1. Explain proper and safe use of excavation equipment and shoring techniques;
2. Determine and check pipeline grade;
3. Inspect a sewer under construction for proper
    a. Bedding materials and construction,
    b. Pipe laying procedures, and
    c. Backfilling and compaction;
4. Describe the need for and duties of a wastewater collection system construction inspector;
5. Contact utility agencies with underground facilities near a construction or repair project BEFORE excavation starts;
6. Test the ability of a wastewater collection system to withstand inflow/infiltration; and
7. Keep accurate records and prepare necessary reports.

SUPPLEMENT

Chapter 3. WASTEWATER COLLECTION SYSTEMS

(Construction, Inspection and Testing)

3.7 CONSTRUCTION

If your job as a wastewater collection system operator is not now or in the future involved in the construction, inspection and testing of such systems you may wish to skip the remainder of this Chapter and proceed to Chapter 4, "Safe Procedures."

3.70 Excavation and Shoring

Most sanitary and storm sewers are constructed within excavated trenches.[13] The following sections will outline the more important aspects of excavation for sewer construction and the shoring of these excavations to eliminate damage to adjacent property and to provide a safe work area during construction.

3.700 Excavation Equipment

The type of equipment to be used for excavating trenches for construction of sewers will be determined to a great extent by the size and depth of the sewer, type of material to be excavated, and the ground surface conditions. The more common types of excavation equipment and the conditions leading to their use are described in the following sections.

TRENCHING MACHINES. Trenching machines are a type of heavy equipment with a series of steel buckets mounted on an endless chain or a wheel. The buckets empty excavated material onto a conveyor belt which discharges it to the side of the trench. When used at moderate depths in stable types of soil where the vertical trench walls can be held with a standard type of shoring, trenching machines are quite productive.

BACKHOES. The most commonly used types of equipment for trench excavations are backhoes. They are manufactured in many sizes with varying depth capabilities and bucket sizes. Backhoes have the ability to excavate trenches with either vertical or sloping sides and, with the addition of a cable sling, can be used to lower large-diameter sewer pipe into a trench, thus eliminating the need for a separate piece of equipment. A backhoe is particularly suitable for excavating through rocky and unstable types of soils. Small, rubber-tired backhoes are quite mobile and are often used for shallow and restricted excavations that are often encountered in easements.

CLAMSHELLS AND DRAGLINES. Clamshell and dragline buckets can be installed on most cranes. Clamshells are seldom used as the primary means of trench excavation due to their low productivity. However, this type of equipment is used when vertical lifts of excavated material in tight quarters are required, such as between shoring and at the headworks of sewer tunnels. Draglines, on the other hand, are most productive in open areas where the bucket may be cast into a wide sloping trench and the excavated material dropped to the side.

BORING AND TUNNELING MACHINES. Boring and tunneling machines are used for construction of sewer lines when they are too deep for trench excavations or the surface over the sewer cannot be disturbed.

SPECIAL EQUIPMENT. Special equipment including air compressors, hydraulic splitters, jackhammers, dynamite, water trucks, and dump trucks are sometimes needed to assist the previously discussed type of excavation equipment when large or solid rocks must be removed from the trench. Blasting of rocks is a hazardous operation requiring the services of specialists.

When high groundwater levels are encountered during trench excavation, the water can be removed from the excavation by use of sump pumps or by use of a system of WELL POINTS,[14] a header pipe and a central pump. The number and spacing of well point connections to the header pipe are dependent upon the ability of water to flow through the soil and the amount of water to be removed. Three-foot intervals are commonly used with a six-inch diameter header pipe and two-foot intervals with an eight-inch diameter header pipe. Whenever groundwater is controlled by lowering the water table, subsidence (dropping) of the ground in the nearby area may occur and cause damage to structures. After work is completed, the groundwater level is allowed to return to its original level at approximately the same rate it was lowered. This is accomplished by regulating the pumping rate used to remove the water. This type of dewatering often reduces the hazards of excavation in unstable soils.

Front-end loaders are used to place bedding and backfill material and to load excess excavated material into dump trucks for hauling away from the job site.

3.701 Location of Utilities

Most wastewater collection systems will be constructed next to or below existing underground utilities in existing streets. Even though most construction plans will attempt to show the location of existing utilities, the information is usually based on utility companies' records and is subject to inaccuracies.

---

[13] *NOTE: In some unusual circumstances, the use of excavated trenches is not appropriate or feasible and it may be necessary to construct sewers above ground. For instances, if surface conditions do not allow open excavation, if the correct grade would be too deep for trenching equipment, or if inverted siphons are impractical for spanning an extensive watercourse, above-ground sewers may be the appropriate alternative. It is also occasionally necessary to construct sewers in tunnels. These conditions are very unusual, however, and will not be described in this manual.*

[14] *Well Points. A hollow, pointed rod with a perforated (containing many small holes) tip. A well point is driven into an excavation where water seeps into the tip and is pumped out of the area. Used to lower the water table and reduce flowing during an excavation.*

Extreme care must be taken to protect underground utilities when you are excavating near them. Most utility companies will, upon request, send a representative to show you the location and approximate depth of their underground utility. Centers for providing communication between a party planning to excavate and utility companies have been established in many localities. Many of these centers use the designation USA, an abbreviation for Underground Service Alert, to list their telephone number in the "white pages" of the local telephone directory. Use this service before you begin excavating for sewer construction and excavate carefully in the vicinity of an underground utility. These precautions will help eliminate costly delays and repairs caused by digging into or through a utility. Property damage and injuries can also be caused by the rupture of a utility conveying a hazardous material or electricity. Determining which party (contractor, sewer agency or utility company) is responsible for payment of the cost of damages resulting from an excavation for a sewer can be difficult, time consuming and expensive. Therefore,
TAKE THE TIME TO PREVENT ACCIDENTS.

3.702 Trench Shoring

Hazardous trenching procedures are a prime cause of death and injury. The National Institute of Occupational Safety reports approximately 75 deaths and over 1000 work related injuries a year are caused by construction excavation cave-ins.

As a result of this high incidence of injury and death from excavation and trench cave-ins, the Federal Occupational Safety and Health Act (OSHA) established regulations for the protection of workers in excavations and trenches. This Act also requires each state to adopt similar regulations. For example, the State of California sets forth its regulations in Title 8, Sections 1503 and 1539-1547 of the Construction Safety Orders.

TRENCH AND EXCAVATION SAFETY GUIDE[15] is an excellent document that is based on these regulations and is published by the State of California. The following sections contain excerpts from this document.

SUPERVISION. All work in an excavation must be supervised by a qualified person.

HAZARDS. Remove trees, poles, boulders, and similar objects which may be hazardous to workers. Do not allow work in or near the excavation until a qualified person has determined that no hazards to workers exist from possible moving ground. Inspect excavations after rain storms, thaws, or other events which may influence the stability of the soil and increase hazards before workers are allowed to enter the excavation. Protect workers who enter excavations five feet deep or more with a system of shoring, sloping trench walls, benching, or equivalent alternative methods. When necessary, provide similar protection for workers in excavations less than five feet deep.

SPOIL. Dump excavated material (spoil) far enough from the trench so that it does not fall back into the trench. When trenches are five feet deep or more, locate the spoil at least two feet back from the edge and on only one side of the trench. Leave the other side open for access. Do not try to contain the spoil by any method which will disturb the soil already in place (such as driving stakes).

ACCESS. Provide a safe and convenient way for workers to enter and leave the excavation. In trenches four feet deep or more, provide a safe means of access (a ladder) within 25 feet of any work area in the excavation. Don't climb up or down shoring braces for access.

CROSSINGS. Install trench crossings with standard guardrails and toe boards when the excavation is more than 7.5 feet deep. Don't try to jump across a trench.

UNDERMINING. Do not excavate beneath the level of the base of an adjacent foundation, retaining wall or other structure until a qualified person has determined that the earthwork will not create a hazard to workers. Support undermined sidewalls so they will support anticipated loads. If the excavation endangers the stability of adjoining structures, shore, brace, or underpin those structures.

RETAINING WALLS. Do not use an existing wall or structure as a retaining wall until it has been determined that it will safely support the additional expected loads.

REMOTE WORK LOCATIONS. Provide barriers to prevent workers from falling into excavations. Barricade or cover all wells, pits, shafts, and caissons. Backfill temporary wells, pits, and shafts as soon as the operation is completed.

WATER ACCUMULATION. Use diversion ditches, dikes, and other methods to prevent surface water from entering the excavation and to drain surrounding areas.

VIBRATION OR SUPERIMPOSED LOADS. Use additional bracing to strengthen shoring in excavations located near streets, railroads, or other sources of vibration and external loads. Take similar precautions when excavations are made in areas that have been previously filled.

SHORING, SLOPING, AND BENCHING SYSTEMS. Provide devices which allow the upper cross braces to be set in place from ground level. In deep trenches where additional braces are needed, workers should proceed downward, protected by cross braces already set in place at the top. When removing shoring, use the reverse procedure by starting at the bottom and working upward to the top.
STANDARD SHORING SYSTEM. Install shoring in accordance with Tables 3.5 and 3.6 and Figures 3.25 through 3.29, or according to plans prepared by a civil engineer registered in the state where the work will be performed.

---

[15] *TRENCH AND EXCAVATION SAFETY GUIDE, CAL/OSHA Communications, 525 Golden Gate Avenue, San Francisco, CA 94102.*

TABLE 3.5 METAL-WOOD SHORING FOR HARD COMPACT SOIL[a]

	UPRIGHTS		BRACES (STRUTS) AT 8' ON CENTERS				STRINGER
			ALUMINUM PIPE		STD. STEEL PIPE		
DEPTH (FEET)	HORIZ SPACING (FEET)	WOOD SIZE (INCHES)	MIN ID (INCHES)	MAX EXCAV WIDTH (FEET)	MIN ID (INCHES)	MAX EXCAV WIDTH (FEET)	(WALER) (WOOD) SIZE
5	8	3×8	2½ (3½)	8 (10)	1½	3	
to	4	2×10	2½ (3½)	8 (14)	1½	3	4×4
7	2	2×8	2½ (3½)	8 (20)	1½	3	4×4
Over 7	8	4×10	2½ (3½)	6 (8)	2	6	
to	4	3×10	2½ (3½)	9 (11)	2½	12	6×8
10	2	3×8	2½ (3½)	12 (16)	3	15	6×8
Over 10	8	6×8	2½ (3½)	6 (7)	2 (2½)	8 (12)	
to	4	4×8	2½ (3½)	8 (10)	2 (2½)	10 (11)	8×8
12	2	3×8	2½ (3½)	10 (15)	2½ (3)	13 (15)	8×8
Over 12	8	6×8	2½ (3½)	5 (6)	2 (2½)	6 (10)	
to	4	4×10	2½ (3½)	7 (9)	2 (2½)	8 (12)	8×10
15	2	3×10	2½ (3½)	9 (13)	2½ (3)	13 (15)	8×10
Over 15	8	6×10	2½ (3½)	4 (5)	2½ (3)	8 (12)	
to	4	4×12	2½ (3½)	6 (8)	2½ (3)	10 (15)	6×12
20	2	3×12	2½ (3½)	8 (11)	2½ (3)	12 (15)	6×12

- Metal pipe braces must be schedule 40, standard steel pipe or equivalent.
- Timber must be "selected lumber".
- Timber members of equivalent "section modulus" may be used for uprights and stringers shown in these tables.
- See page 17 for screw jack installation.
- Numbers in parentheses indicate maximum safe span for a specified diameter pipe.
- Tables may be modified by a civil engineer.
- Metal sheeting or other material equivalent to the strength of the wood members may be used.
- Place stringers to develop maximum strength (long side horizontal).

TABLE 3.6 HYDRAULIC SHORING FOR HARD COMPACT SOIL[a]

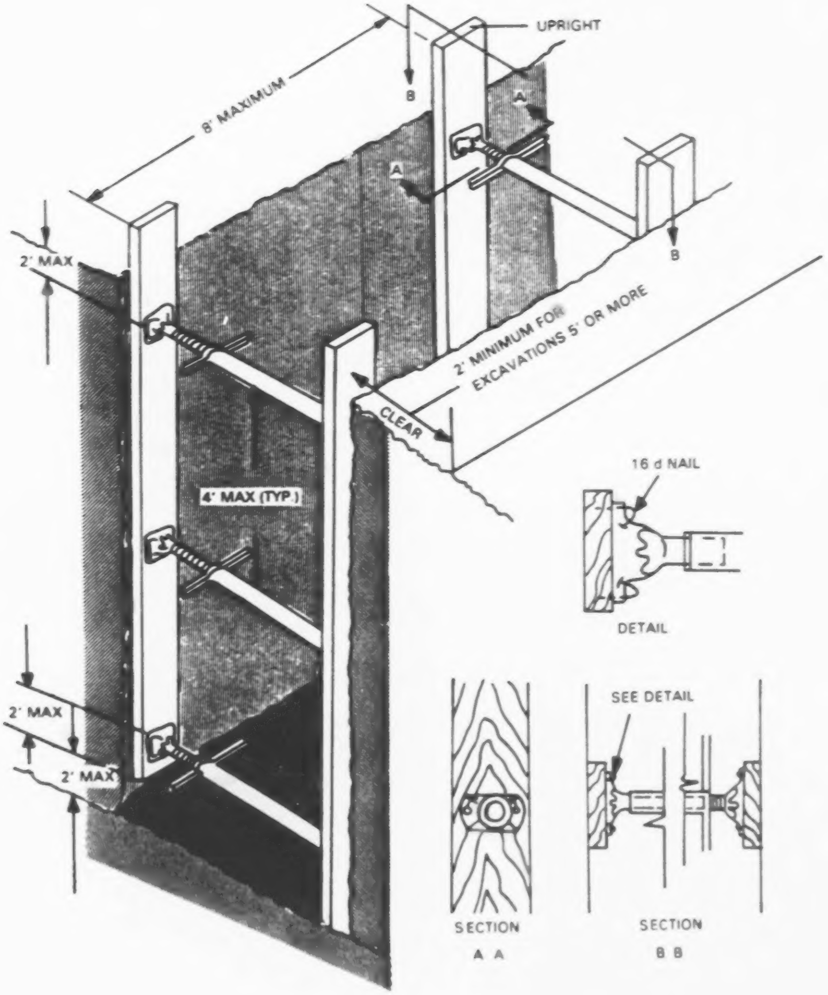
	UPRIGHTS		STRINGERS (WALER)		BRACES (STRUTS)			
DEPTH (FEET)	HORIZONTAL SPACING (FEET)	SIZE ALUMINUM RAIL	SIZE ALUMINUM RAIL	VERTICAL SPACING (FEET)	HYDRAULIC CYLINDERS	HORIZ. SPACING (FEET) '	MAX. EXCV. WIDTH (FEET)	
5	8	8" Wide	6" Wide	5	2" ID-2½" OD	8 cc	12	20
to		Standard	Standard					
7	*	***	***					**
Over 7	8	8" Wide	6" Wide	5	2" ID-2½" OD	8 cc	9	20
to		Standard	Standard					
12	*	***	***					**
Over 12	6	8" Wide	6" Wide	5	2" ID-2½ OD	6 cc	9	20
to		Standard or	Standard or					
16	*	HD	8" Wide HD	5	2" ID-2½" OD			**
Over 16	6	8" Wide	6" Wide	4	2" or 3" ID	4 cc	9	20
to		Standard or	Standard or		or			
20	*	HD	8" Wide HD	4	2½" or 3½" OD			**

* Plywood may be used behind uprights.
** Use a 3½ × 3½ × 3/16" steel oversleeve to Std. 2" ID. No steel oversleeve required on 3" ID.
*** See Hydraulic Shoring Association Manual for strength of rails.

- Tables may be modified by a civil engineer.

---

[a] *TRENCH AND EXCAVATION SAFETY GUIDE, CAL/OSHA Communications, 525 Golden Gate Avenue, San Francisco, CA 94102.*


UPRIGHT
8' MAXIMUM
B
A
A
B
2' MAX
2' MINIMUM FOR EXCAVATIONS 5' OR MORE
CLEAR
4' MAX (TYP.)
16 d NAIL
DETAIL
2' MAX
2' MAX
SEE DETAIL
SECTION A A
SECTION B B

NOTE use of trench screw jacks holding planks in place

Fig. 3.25 Minimum shoring requirement in hard compact soil
(Reproduced from TRENCH AND EXCAVATION SAFETY GUIDE, Cal/OSHA Communications, 525 Golden Gate Avenue, San Francisco, CA 94102)

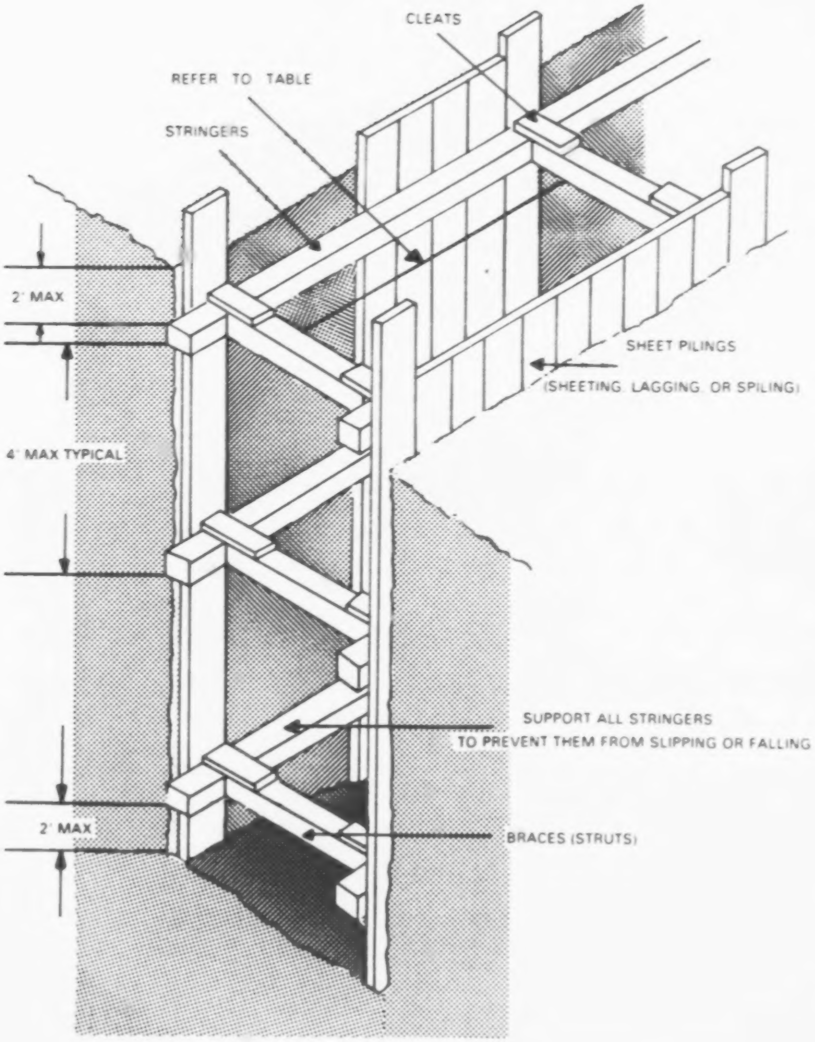

CLEATS
REFER TO TABLE
STRINGERS
2' MAX
4' MAX TYPICAL
SHEET PILINGS
(SHEETING, LAGGING, OR SPILING)
SUPPORT ALL STRINGERS
TO PREVENT THEM FROM SLIPPING OR FALLING
2' MAX
BRACES (STRUTS)

Fig. 3.26 Close sheeting method in running soil
(Reproduced from TRENCH AND EXCAVATION SAFETY GUIDE, Cal/OSHA Communications,
525 Golden Gate Avenue, San Francisco, CA 94102)

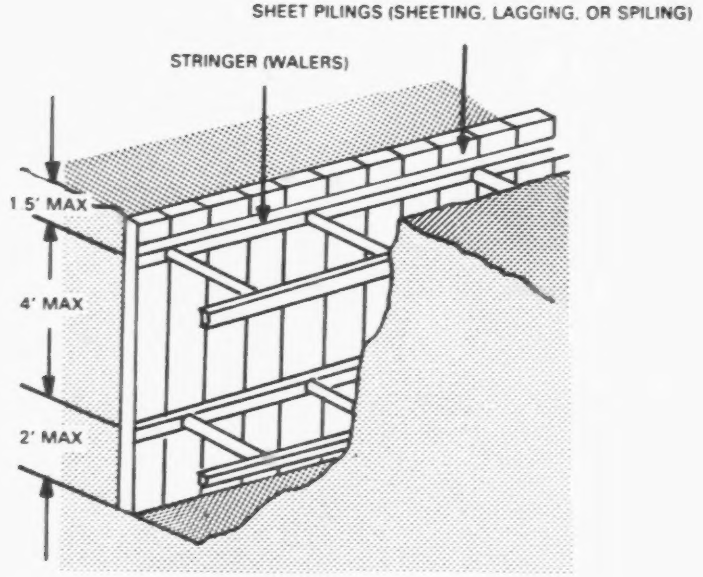
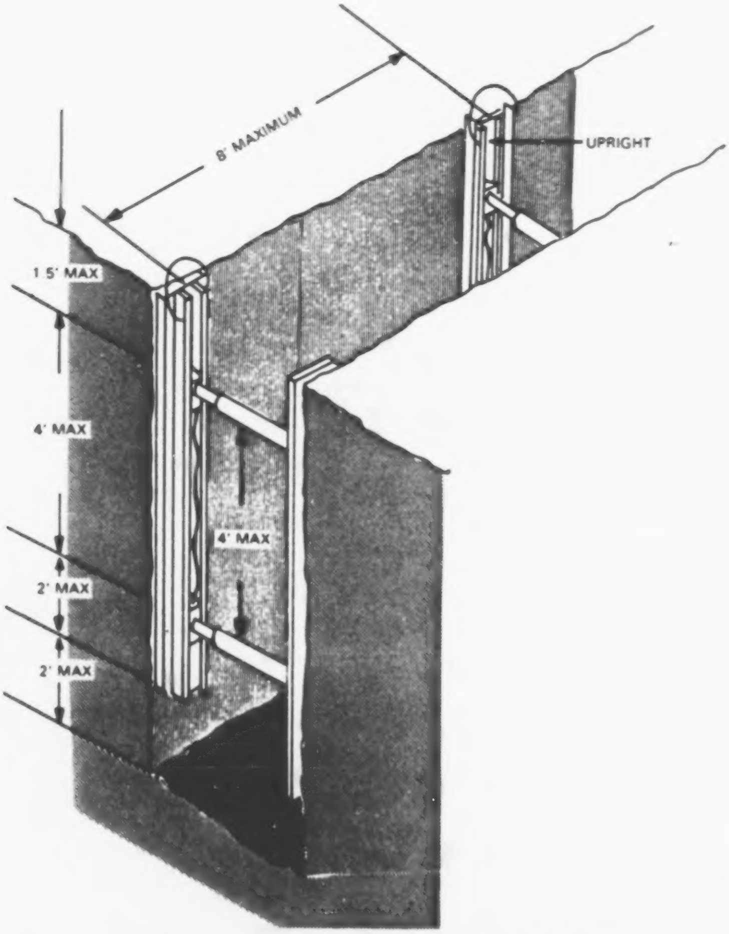

SHEET PILINGS (SHEETING, LAGGING, OR SPILING)
STRINGER (WALERS)
1.5' MAX
4' MAX
2' MAX

Fig. 3.27 Close sheeting method in running soil
(Reproduced from TRENCH AND EXCAVATION SAFETY GUIDE, Cal/OSHA Communications, 525 Golden Gate Avenue, San Francisco, CA 94102)


8' MAXIMUM
UPRIGHT
1.5' MAX
4' MAX
4' MAX
2' MAX
2' MAX

NOTE use of aluminum hydraulic cylinder shores

Fig. 3.28 Minimum shoring requirement in hard compact soil — hydraulic shore
(Reproduced from TRENCH AND EXCAVATION SAFETY GUIDE, Cal/OSHA Communications, 525 Golden Gate Avenue, San Francisco, CA 94102)

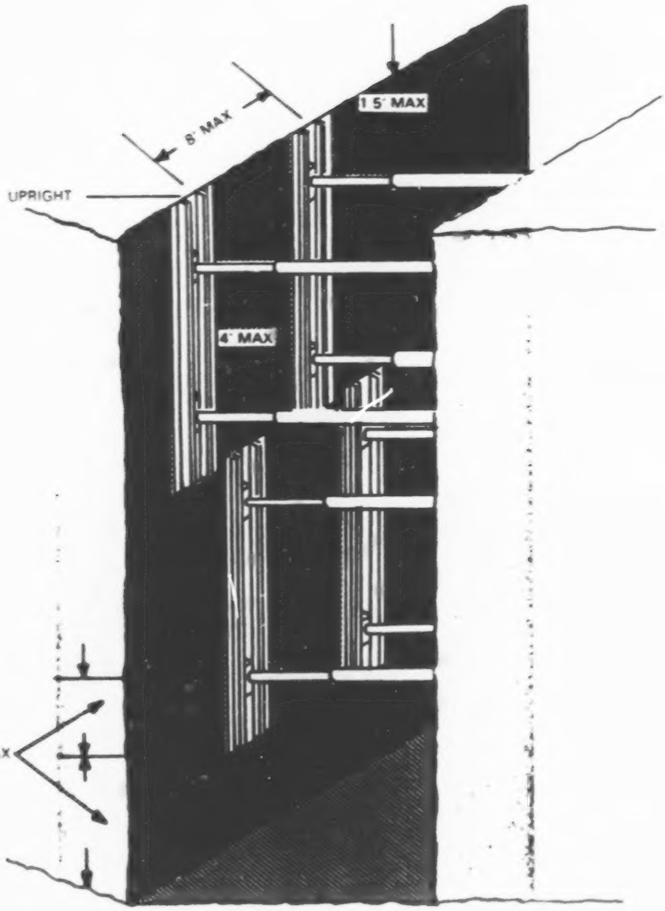

8' MAX
1.5' MAX
UPRIGHT
4' MAX
2' MAX

Fig. 3.29 Typical installation in hard compact soil — hydraulic shore
(Reproduced from TRENCH AND EXCAVATION SAFETY GUIDE, Cal/OSHA Communications, 525 Golden Gate Avenue, San Francisco, CA 94102)

Shoring must be composed of:

- Solid wood sheeting or wood sheet-piling not less than two inches thick.
- Plywood at least 1-1/8 inches thick.
- Wood uprights at least 2 inches by 8 inches (planks).
- Wood braces and diagonal shores at least 4 inches by 4 inches and not subjected to compressive stress in excess of values given by the following formula:

$$S = 1300 - (20\ L/D)$$

Maximum Ratio (L/D) = 50

L - length, unsupported (in inches)

D - least side of the timber (in inches)

S - allowable stress (in pounds per square inch of cross section)

- Wedge or cleat diagonal shores (struts) must be installed at the bulkhead end (partition at end of trench). If diagonal shores bear on the ground, they should not impose loads in excess of the test-determined soil-bearing values. (Allow for the horizontal component of force.) Do not place diagonal shores at an angle greater than 45 degrees from the horizontal. Securely anchor tie rods when they are used to restrain the top of sheeting (planks) or other restraining systems. Assume that there is full loading due to groundwater when using tight sheeting or sheet piling (unless full loading is prevented by weep holes, drains, or other methods).

- Provide additional stringers, ties, and bracing to allow temporary removal of individual supports. Required thickness of sheeting and spacing of shores are as follows:

Minimum Rough Thickness of Sheeting or Lagging	Maximum Spacing of Shores
2 inches	4 feet
3 inches	7 feet

TRENCH SHORING SYSTEMS. Do not slope a shored trench in excess of 15 degrees from the vertical. Make uprights at least two inches in nominal thickness. Plywood panels at least 3/4 inches thick may be installed behind uprights to hold loose material not likely to impose heavy loads. Extend uprights to the top of the trench and to within at least two feet of the bottom. If running soil (sand) is encountered, extend uprights to the bottom of the trench.

CROSS BRACES. Always use at least two cross braces. Install one horizontal brace for each four-foot zone or partial zone measuring two feet or more. Use metal screw-type trench jacks with a base on each end or timbers placed horizontally against the uprights or stringers. Hydraulic braces may also be used.

PROTECTIVE SHIELDS AND WELDING HUTS. Plans for protective shields and welding huts must be prepared by a registered civil engineer. Construct protective shields and welding huts out of steel or other materials providing equivalent strength. They must provide at least as much protection as adequate shoring would provide.

SLOPING OR BENCHING SYSTEMS. When sloping is used as a substitute for shoring, the slope should be at least 3/4 horizontal to one vertical, unless the instability of the soil requires a flatter slope. Engineers decide whether to use shoring or sloping on the basis of safety and costs. Exceptions: In hard compact soil where the depth of the excavation or trench is eight feet or less, make a vertical cut of 3.5 feet with a slope of 3/4 horizontal to one vertical. In hard, compact soil where the depth of the excavation or trench is twelve feet or less, make a vertical cut of 3.5 feet with a slope of one horizontal to one vertical. When benching in hard, compact soil, use a slope ratio of 3/4 horizontal to one vertical, or flatter with a first vertical rise of 3.5 feet maximum and all subsequent vertical rises at a maximum of two feet.

3.71 Controls

Controls must be used to ensure that sewer lines and appurtenances are constructed as planned. Precision is important when the slope of a typical eight-inch diameter sewer line is approximately a 3/16 inch drop for each four-foot length of pipe (0.004 ft/ft). Even slight deviations from the designed slope of a sewer line will cause sags that interfere with the normal flow of wastewater and will cause maintenance problems in the future, including stoppages and the generation of toxic, odorous and corrosive hydrogen sulfide gas.

3.710 Control Points

Using a sewer plan and profile, surveyors set control points, usually at 50-foot intervals, to guide accurate excavation. The control points are stakes driven into the ground or nails and washers (shiners) driven into pavement at a designated offset from the sewer center line as shown in Figure 3.30. The precise elevation of a control point is determined by its relation to a previously determined control elevation called a "bench mark." Figure 3.21 (page 58) illustrates the field notes of a survey to place and determine the elevation of the controls for the sanitary sewer set forth in the plan and profile illustrated by Figure 3.24 (page 64).

Note that the control points have been set on a 5-foot right offset from the sewer center line as you face upstream with respect to the wastewater flow. The size of the sewer and method of trench excavation will determine the best side and offset distance for the controls. Also note that the distance of the control point from the starting point along the sewer is expressed in terms of 100-foot stations and usually to one-hundredths of a foot. For example, a manhole 425.26 feet from the beginning of construction would be located at station (sta)4+25.26. Construction controls placed at 50-foot intervals would be designated 0+00, 0+50, 1+00, 1+50 and so on.

Surveyors mark the offset of the control points from the sewer center line and the amount of cut in feet from the top of the control point to the invert of the sewer on a grade stake or on the pavement exactly opposite the control. In Figure 3.30 the markings on the guard stake are as follows:

5	- Offset 5 feet
0+00	- Station 0+00 or distance from starting point
C	- Cut
7^{99}	- Cut 7.99 feet or depth of sewer invert below hub.

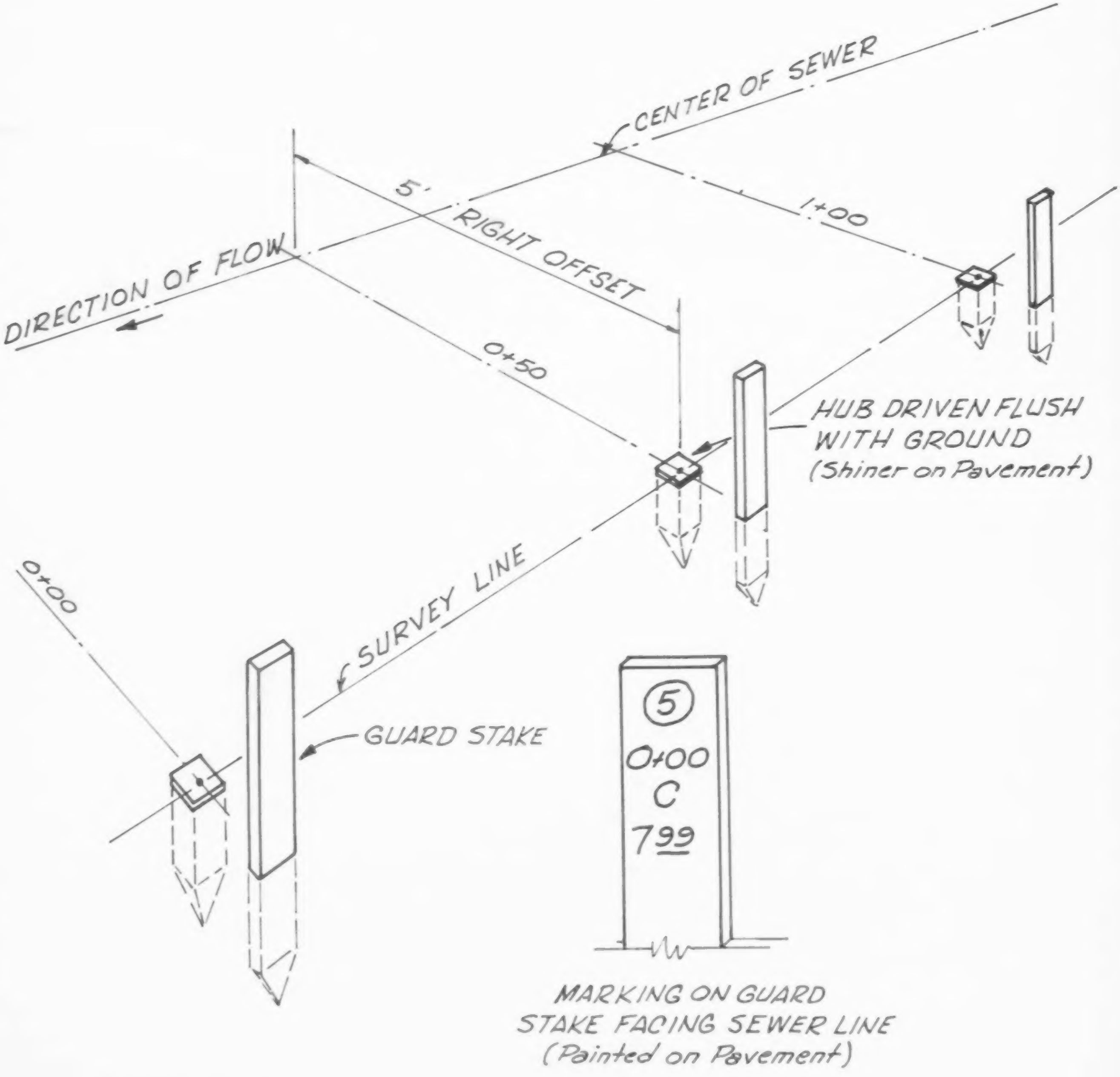
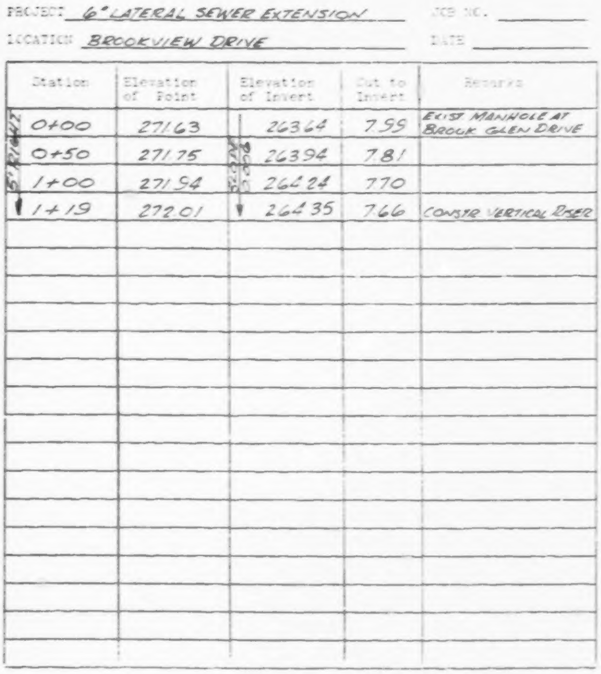

CENTER OF SEWER
5' RIGHT OFFSET
1+00
DIRECTION OF FLOW
0+50
HUB DRIVEN FLUSH
WITH GROUND
(Shiner on Pavement)
SURVEY LINE
0+00
GUARD STAKE
5
0+00
C
7.99
MARKING ON GUARD
STAKE FACING SEWER LINE
(Painted on Pavement)

Fig. 3.30 Control points for sewer construction

The cut from the top of the control points to the invert of the sewer is calculated by knowing the given elevation of the beginning point of the sewer to be constructed, the sewer slope (grade), the distance from the beginning point to the control point, and the elevation of the control. Figure 3.31 shows the cut sheet calculations for the sewer illustrated by Figure 3.24 using the field notes in Figure 3.21.



PROJECT 6" LATERAL SEWER EXTENSION JOB NO. ________

LOCATION BROOKVIEW DRIVE DATE ________

Station	Elevation of Point	Elevation of Invert	Cut to Invert	Remarks
0+00	271.63	263.64	7.99	EXIST MANHOLE AT BROOK GLEN DRIVE
0+50	271.75	263.94	7.81	
1+00	271.94	264.24	7.70	
1+19	272.01	264.35	7.66	CONSTR VERTICAL RISER

5' RIGHT

Fig. 3.31 Cut sheet for sewer construction

To prepare a sewer cut sheet, as illustrated by Figure 3.31, the following steps are taken:

IN THE FIELD, SURVEYOR:

1. Sets control hub or shiner 5 feet to right of line and records *STATION.*
2. Determines elevation of established hub or shiner, *ELEVATION OF POINT.*
3. Records *ELEVATION OF INVERT* for Station 0+00 "Exist. manhole at Brookglen Drive" as *263.64.*

IN THE OFFICE OR IN THE FIELD:

4. Determine slope of the line to be constructed from plan or profile, *SLOPE = 0.006 FT/FT.*
5. Calculate *ELEVATION OF INVERT* for each *STATION* by multiplying Station (a) times slope (b) and adding result (c) to elevation of existing manhole invert (d) to obtain *ELEVATION OF INVERT* (e).

Station (a)	×	Slope (b)	=	Rise (c)	+	Exist. (d)	=	Invert (e)
50		0.006		0.30		263.64		263.94
100		0.006		0.60		263.64		264.24
119		0.006		0.71		263.64		264.35

6. To calculate *CUT TO INVERT*, take *ELEVATION OF CONTROL* (a) and subtract *ELEVATION OF INVERT* (b), to obtain *CUT TO INVERT* (c).

Station	Elevation of Control (a)	−	Elevation of Invert (b)	=	Cut to Invert (c)
0+00	271.63		263.64		7.99
0+50	271.75		263.94		7.81
1+00	271.94		264.24		7.70
1+19	272.01		264.35		7.66

By following this step-by-step procedure, you can learn to calculate cuts to inverts and others can easily check your work and show you where any errors were made in calculations.

3.711 Use of Construction Controls

The line and grade controls for the sewer are used first to determine the location and depth of the sewer trench and second for laying the sewer pipe to the proper line and grade.

STRING LINE. The project foreman will place steel rods immediately adjacent to the control point (stake or nail) and will mark on each rod an even number of feet of cut to the sewer invert. For example, if the cut from a control point to the invert is 7.99 feet, the foreman would mark a 9.00-foot cut by measuring 1.01 feet up from the control point to a point on the steel rod. A grade string line then would be stretched between three consecutive control points on the steel rods. The string should be perfectly straight; any departure from a straight line indicates an error has been made in either the control survey or setting of the string line. Figure 3.32 illustrates setting of the grade string line and the 3-point method of detecting errors.

The excavation equipment operator uses the grade string line to control the depth of cut. In most instances sewer trenches are excavated a pre-determined distance below the invert of the sewer to provide for the thickness of the pipe's wall and for imported bedding under the pipe. For instance, if the sewer pipe has a wall thickness of 0.10-foot and a 0.25-foot thick bedding will be used, a 9-foot cut from the grade line to the pipe invert would become a 9.35-foot cut to the bottom of the trench.

A trenching machine, as described in Section 3.700, is equipped with an indicator that follows along the string line when the operator has the excavating bucket line on line and grade. When backhoes, clamshells, or draglines are used to excavate a trench, the equipment operator's assistant will check the line and grade by the use of a grade pole illustrated in Figure 3.33.

The string line used for controlling the trench excavation is also frequently used as a control guide when laying the sewer pipe. A grade pole, as illustrated in Figure 3.33, is used to measure the calculated distance between the string line and the top of the pipe being laid when the pipe invert is on the prescribed grade. For example, when using a 9-foot string line to lay an 8-inch (0.67 ft) diameter sewer pipe with a 0.12-foot wall thickness, the length of the grade pole would be (9.00 - 0.67 - 0.12) 8.21 feet. Controlling pipe laying with a grade pole is illustrated in Figure 3.34.

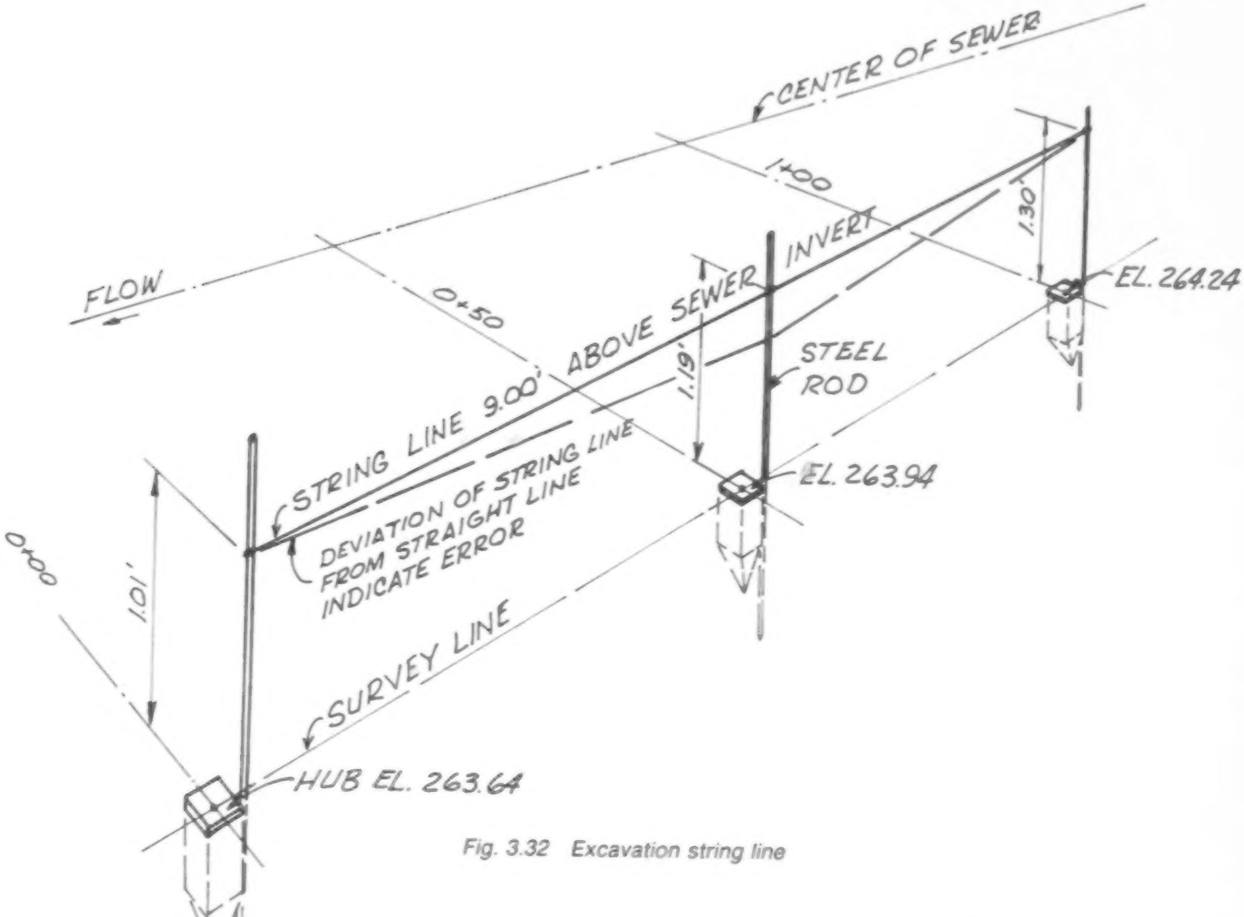

CENTER OF SEWER
FLOW
0+50
1+00
1.30'
EL. 264.24
STRING LINE 9.00' ABOVE SEWER INVERT
1.19'
STEEL ROD
EL. 263.94
DEVIATION OF STRING LINE FROM STRAIGHT LINE INDICATE ERROR
0+00
1.01'
SURVEY LINE
HUB EL. 263.64

Fig. 3.32 Excavation string line

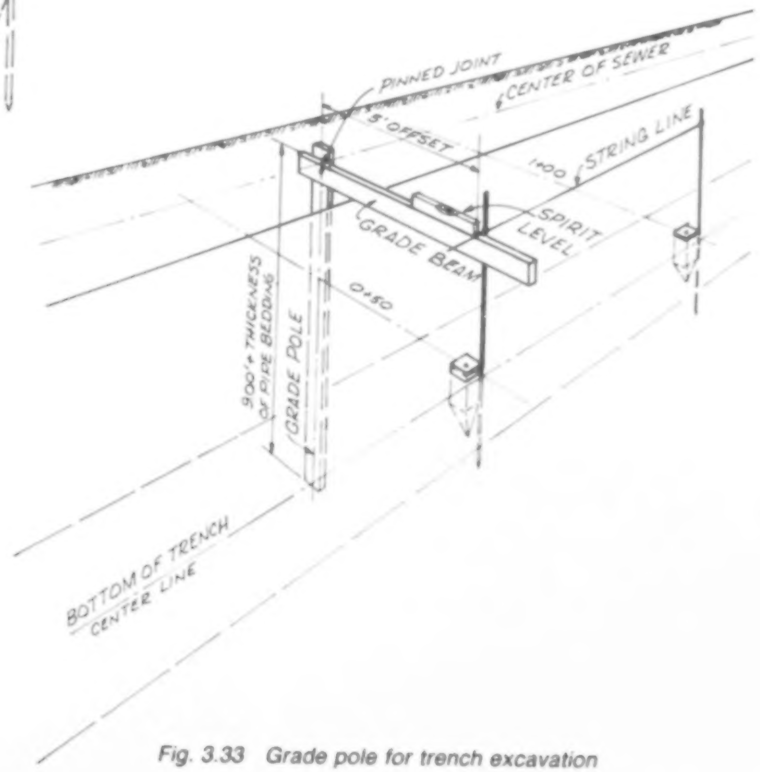

PINNED JOINT
CENTER OF SEWER
5' OFFSET
1+00
STRING LINE
SPIRIT LEVEL
GRADE BEAM
0+50
9.00' + THICKNESS OF PIPE BEDDING
GRADE POLE
BOTTOM OF TRENCH CENTER LINE

Fig. 3.33 Grade pole for trench excavation

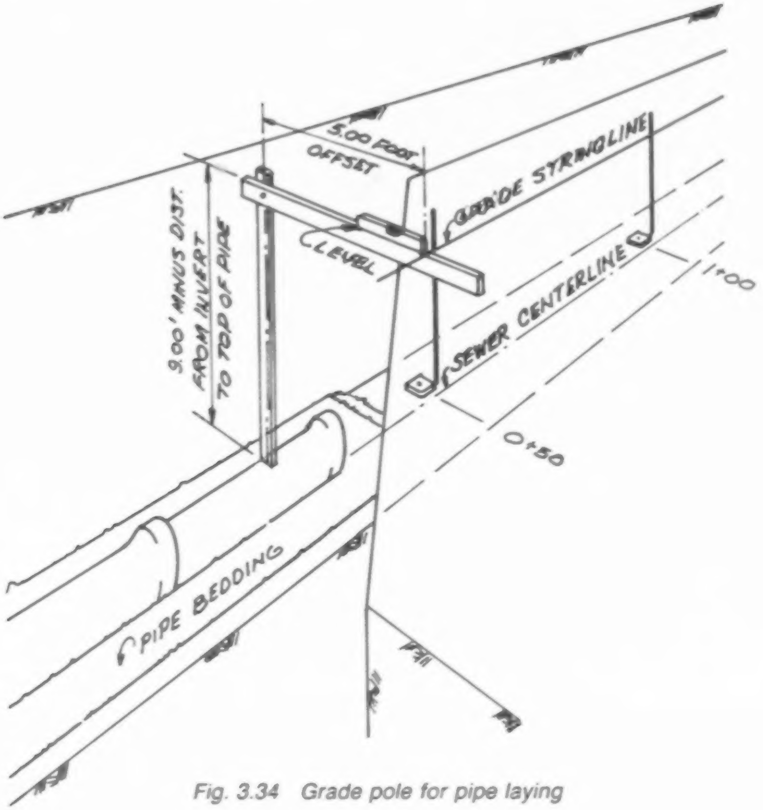


Fig. 3.34 Grade pole for pipe laying

BATTER BOARD. Batter boards can be used as illustrated in Figure 3.35 to control the laying of sewer pipe after the trench has been excavated. However, this type of control is difficult to set up, particularly for wide trenches, and the boards interfere with placement of the pipe.

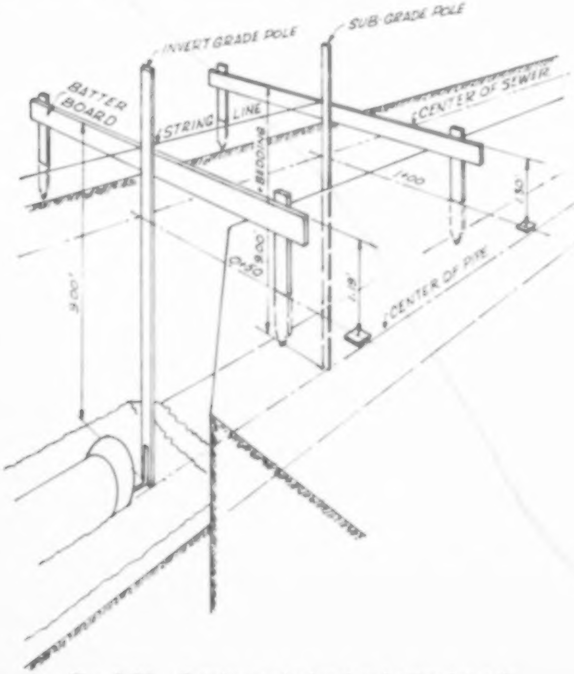
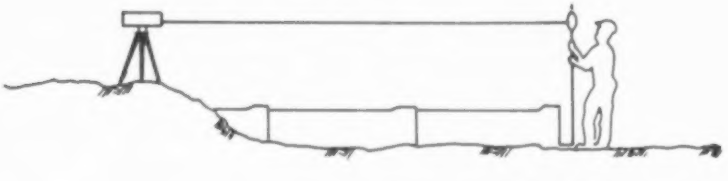


Fig. 3.35 Grade control using batter boards

FIXED-BEAM LASER. A fixed beam laser projects a bright red, highly focused beam of light along the line of the sewer to be constructed at a determined distance above the sewer invert grade. The beam is intercepted by a target creating a small bright spot of light that serves as a reference point. Refer to the manufacturer's instructions to set the laser for the desired grade of the sewer line. Position and level the laser on the sewer line in one of the several locations illustrated in Figure 3.36. Use the control points described in Section 3.710 to position the laser on the designated line and grade. Measure the projected laser beam from another control point at least 100 feet ahead of the laser and make the appropriate adjustments to its position. Several types of targets are illustrated in Figure 3.36; use one of these to determine the proper depth of trench excavation and pipe position. When the laser is positioned in the sewer line for pipe laying control, check the beam for deflection by atmospheric conditions and take appropriate ventilation measures to eliminate any inaccuracy.

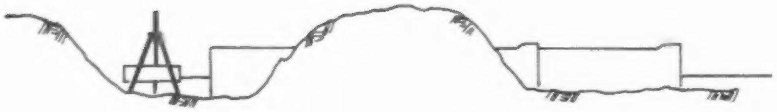
3.72 Sewer Pipe Bedding and Initial Backfill

Sewer pipe bedding is the material upon which the pipe is laid and which serves as its foundation. Initial backfill is the material surrounding the sewer pipe. The type of bedding material, initial backfill, and the care used in placement greatly affect the ability of a pipe to support the load created by backfilling the trench. The following sections briefly describe types of bedding and initial backfill materials and their ability to assist sewer pipe in supporting backfill loads. For more information on pipe bedding and initial backfill, refer to Chapter 9 of *GRAVITY SANITARY SEWER DESIGN AND CONSTRUCTION,* published by the Water Pollution Control Federation, 601 Wythe Street, Alexandria, Virginia 22314-1994.



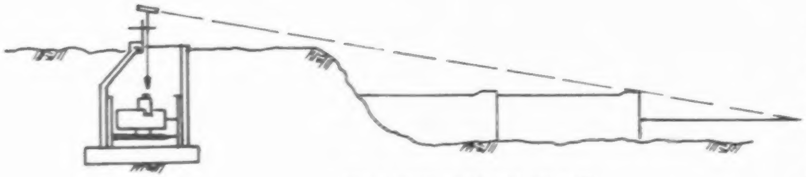
OVER-THE TOP

A SEWER LASER CAN BE SET UP ON A TRIPOD OR A THREE POINT TRIVET PLATE IN THE EXCAVATION, ABOVE IT OR ON THE PIPE. THE LASER TARGET IS MOUNTED ON A POLE AND ADJUSTED TO GIVE THE DISTANCE FROM THE BEAM TO THE PIPE INVERT. A LEVEL VIAL ON THE POLE INDICATES A VERTICAL POSITION.



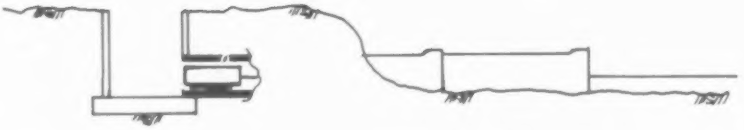
OPEN EXCAVATION

THE VERSATILITY AND FLEXIBILITY OF A SEWER LASER PERMITS A VARIETY OF OPEN EXCAVATION SET-UPS WITH THE BEAM PROJECTED DOWN THE CENTERLINE OF THE PIPE OR OVER-THE-TOP.



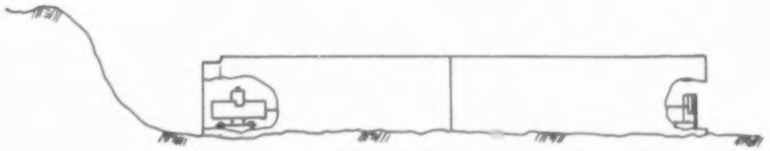
IN-THE-MANHOLE

A SEWER LASER CAN BE SET UP IN A MANHOLE UTILIZING A TRANSIT TO SET THE SEWER LINE ACCURATELY. THE TRANSIT IS PLUMBED OVER THE LASER ON A MOUNT THAT CLAMPS TO THE MANHOLE EDGE. THE LASER BEAM IS PROJECTED ALONG THE PIPE CENTERLINE.



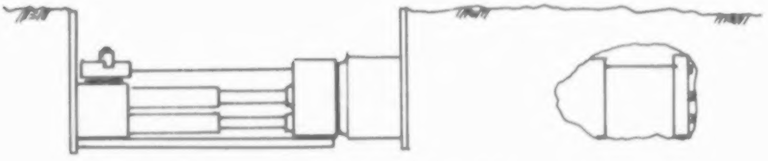
IN-SMALL-PIPE

SOME SEWER LASERS CAN BE SET DIRECTLY INSIDE IN PIPES AS SMALL AS 6-INCHES IN DIAMETER. THIS ALLOWS FAST SET-UPS THE SECOND DAY AS WELL AS THE VESATILITY TO MEET SITUATIONS IN WHICH THE LASER CANNOT BE SET-UP IN A MANHOLE.



IN-LARGE-PIPE

FOR LARGE PIPE, A LASER CAN BE SET-UP DIRECTLY ON THE INVERT OF THE PIPE USING THE THREE POINT TRIVET PLATE.



PIPE-JACKING

ELECTRONIC SELF LEVELING SEWER LASERS CAN ALSO BE USED TO PROVIDE LINE AND GRADE CONTROL IN PIPE-JACKING OPERATIONS. THE LASER IS SET-UP IN THE JACKING PIT AND THE TARGET IS MOUNTED ON THE CUTTING SHIELD.

Fig. 3.36 Grade control using fixed-beam laser

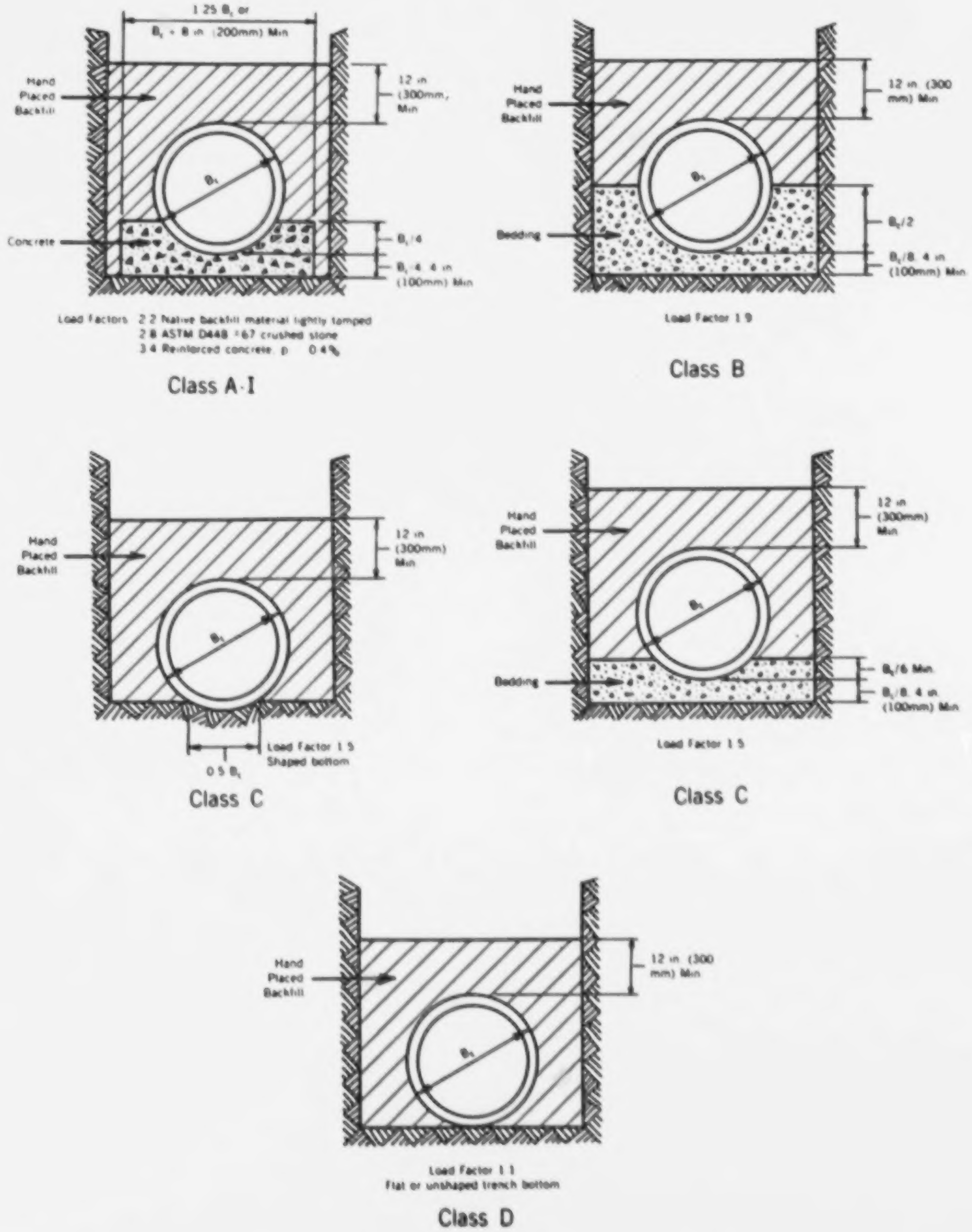
Also, manufacturers of most sewer pipe will, upon request, supply information on the effects types of bedding and initial backfill have upon the load supporting capacity of their pipe.

3.720 Effects of Bedding and Initial Backfill on Rigid Pipe

Manufacturers of rigid sewer pipe usually will specify the load supporting strength of their pipe based on a "three-edged bearing test" conducted in a laboratory and usually expressed as pounds per lineal foot of pipe. For example, if the standard strength of 8-inch diameter vitrified clay pipe is 2,200 pounds per foot, it means the pipe will support this load without cracking.

Similarly, types of sewer pipe bedding have been given a standard class designation indicating the ability of the bedding to assist sewer pipe in supporting trench backfill loads. These bedding designations or ratings take into account the three-edge bearing test load. The rating is called a "bedding factor" and the three-edge bearing load is given a value of 1.

CLASSES OF BEDDING. The standard classes of rigid sewer pipe bedding and their load factors "bedding factors" are shown in Figure 3.37. For example, an 8-inch vitrified clay pipe that has a three-edge bearing load supporting strength of 2,200 pounds per foot will have a supporting strength of (2,200 lbs/ft x 1.5) = 3,300 pounds per foot when laid on a Class C type of bedding.


1.25 B_c or
B_c + 8 in (200mm) Min
Hand Placed Backfill
12 in (300mm) Min
B_c
Concrete
B_c/4
B_c/4, 4 in (100mm) Min
Load Factors 2.2 Native backfill material lightly tamped
2.8 ASTM D448 #67 crushed stone
3.4 Reinforced concrete, p = 0.4%
Hand Placed Backfill
12 in (300 mm) Min
B_c
Bedding
B_c/2
B_c/8, 4 in (100mm) Min
Load Factor 1.9
Hand Placed Backfill
12 in (300mm) Min
B_c
0.5 B_c
Load Factor 1.5
Shaped bottom
Hand Placed Backfill
12 in (300mm) Min
B_c
Bedding
B_c/6 Min
B_c/8, 4 in (100mm) Min
Load Factor 1.5
Hand Placed Backfill
12 in (300 mm) Min
B_c
Load Factor 1.1
Flat or unshaped trench bottom

Class A-I

Class B

Class C

Class C

Class D

Fig. 3.37 Classes of bedding for rigid sewer pipe

FACILITATION OF PIPE LAYING. In addition to assisting sewer pipe in supporting trench backfill loads, a granular type bedding, such as Classes B and C, provides an easy means of establishing a true grade on an imperfect and undercut trench bottom. Also, granular material can easily be arranged to provide holes for pipe bells when laying sewer pipe and to provide for the specified surface contact between the pipe barrel and bedding material.

For these reasons, Classes B and C are the most commonly used types of sewer pipe bedding. Class D is impermissible bedding which means that this type of bedding should not be used unless specific construction conditions require it.

3.721 Effect of Bedding and Initial Backfill on Flexible Pipe

Flexible pipes depend on the soil surrounding them to help support the load of trench backfill. As the weight of backfill exerts pressure on the pipe, it flexes or deflects, as illustrated in Figure 3.22 (page 61). The sides of the pipe move outward against the soil. Unless the surrounding soil or bedding resists this flexing at some point, the load will simply deflect the pipe to the point of collapse. Therefore, the compaction of the initial backfill around a flexible pipe is very important to assure that it will not be deflected beyond the allowable amount when the trench backfill is applied and compacted. As a rule of thumb, deflection of flexible pipe should not exceed five percent of the inside diameter of the pipe.

For a given load on a flexible pipe the deflection of the pipe will decrease in proportion to the stiffness of the pipe and the compaction of the soil. Also, as the pipe stiffness diminishes, the need for a greater support from the enveloping soil increases. Data on long-term deflection of flexible pipe in different bedding and backfill conditions can usually be obtained from pipe manufacturers. Also, information on flexible pipe bedding classifications and deflection can be found in *GRAVITY SANITARY SEWER DESIGN AND CONSTRUCTION*, published by the Water Pollution Control Federation.

3.722 Bedding Materials

Some comments on the sewer pipe bedding and initial backfill materials illustrated in Figure 3.37 will be helpful in understanding their use.

CONCRETE. Low strength (2,000 pounds per square inch) portland cement concrete is used in the Class A sewer pipe bedding and initial backfill to develop a load factor ranging from 2.2 to 3.4 depending upon the extent of steel reinforcement. This type of bedding is expensive and, as a consequence, it is only used in extremely deep trenches where the type of rigid pipe material and wall thickness combined with a less expensive bedding class will not produce the necessary load supporting strength.

GRANULAR MATERIAL. Crushed rock aggregate, with 1/4-inch to 3/4-inch particle size, is the material most commonly used to construct the Classes B and C bedding. It has a fairly high bedding factor (1.5 to 1.9), is moderately priced, and is relatively easy to work with when laying pipe. This type and size of material is superior to sand or pea gravel for bedding and initial backfill material. In some locations water may flow through the bedding material in the trench to downstream manholes where the water may infiltrate into the collection system.

Greater care must be taken in compacting sand bedding material than when aggregate is used. Also, sand has a tendency to move if water jetting is used to compact the subsequent trench backfill or if the trench area is re-excavated at a later time to construct other facilities. Pea gravel, due to its smooth and somewhat circular shape, also has some of the undesirable characteristics of sand bedding material.

NATIVE MATERIAL. Sometimes it is not practical to import material to construct a bedding or the soil conditions are unsuitable. In such cases, the native soil in a trench bottom can be used to construct a Class D bedding. Extreme care must be taken in excavating the trench bottom to true grade in order to produce an undisturbed and compacted trench bottom. Also, the low bedding factor of 1.1 requires the use of high-strength pipe or shallow sewer depths.

3.723 Bedding Construction

Some sewer pipe bedding and initial backfill construction considerations became apparent as you study the classes of bedding illustrated in Figure 3.37. The following comments point up some of the less apparent considerations.

CLASS A BEDDING. When a concrete bedding is used, the rigid pipe must be supported (usually on concrete blocks or clay bricks) and held to true line and grade when the concrete is placed under the pipe. This is not an easy task since the pipe, particularly in smaller diameters, will tend to float out of alignment and grade.

The concrete can be poured into the trench without use of forms providing the bottom is undisturbed, clean and compact, and the trench is not too wide.

When a concrete backfill is used over a granular bedding, the problem of the pipe floating during placement of the concrete is lessened. However, uniform placement is essential to maintaining alignment. Also, a waterproof liner may have to be placed over the top of the granular bedding to stop a rapid flow of water from the concrete into the bedding.

CLASSES B AND C BEDDING. When a Class B or C bedding is constructed, it is essential that the bottom and sides of the trench be cleaned of all loose material prior to the placement of the granular bedding material. Initial trench backfill of native material for a height of six inches above the pipe should be free of rocks, mechanically compacted in about six-inch layers with the proper moisture being maintained in the backfill material. Since it is difficult and expensive to compact native backfill under and around the pipe, granular material, which requires no compaction, is quite often substituted for the native backfill material.

Care should be exercised in using granular materials for pipe bedding and initial backfill. If the material contains significant voids or spaces, silty or sandy soils tend to move into these voids. This soil migration occurs particularly where groundwater conditions exist which may cause excess loss of pipe support or line and grade change in the pipe after installation is complete. Well graded material with sufficient fines can be used to minimize soil migration into the bedding and backfill material.

CLASS D BEDDING. If Class D bedding is used, it is extremely important to have the trench bottom cleaned of all loose material and at a true grade. Care must be taken in the excavation of bell holes not to disturb the foundation under the pipe barrel. In no instance should the pipe rest on the joints and the initial backfill material used to attempt to develop a foundation for the pipe barrel.

3.724 Special Pipe Foundations

In most instances, a trench bottom will support the combined load of bedding material, pipe, wastewater, and trench backfill since their total weight will be about the same as the material excavated from the trench for construction of the sewer. However, sometimes extremely poor soil conditions (such as fill area) combined with large diameter pipe may require a firm, constructed foundation to keep the sewer on a true grade. In these situations, pile-supported concrete or timber cradles (saddle piling) are used to support the pipe. Design and construction of this rarely used type of sewer pipe support is beyond the scope of this manual.

3.73 Pipe Laying

Most manufacturers of sewer pipe furnish instructions for laying and joining their pipe and these instructions can be obtained by writing the manufacturers. Thoroughly understand these instructions before attempting to lay pipe. Contact the local manufacturer's representative if you need more help.

The following comments provide a general overview of pipe laying and joining procedures and are generally applicable to all types of sewer pipe materials.

3.730 Handling of Pipe

Care should be taken in unloading and storage of the pipe at the construction site to avoid any damage to the pipe or joints. No pipe should be handled by hand unless it can be done safely without dropping and damaging the pipe or hurting the operators. Proper lifting equipment should be used in removal of the large diameter pipe from the transport vehicle to the ground. The barrel should be supported on a block of wood at the spigot end for its protection.

The proper equipment should be used to lower the pipe into the trench. When large diameter pipe is being laid, the handling equipment should have adequate capacity for lifting and maneuvering the pipe into the trench. The pipe sling or hook should not damage the pipe.

The following safety rules apply to the handling of sewer pipe:

1. Use barricades, traffic cones and high level flags to identify the work area when unloading pipe within streets.
2. Use the proper mechanical equipment, cable, slings and closed hooks rated for the weight of pipe being lifted.
3. Keep crane booms at least 10 feet away from overhead electrical wires.
4. Make sure operators wear hard hats and stand clear of pipe being moved.
5. If pipe is stored in a street at the construction site, surround it with barricades and flashing lights. Block the pipe to prevent rolling.

3.731 Placement of Pipe

Small diameter pipe (up to 10 inches in diameter) can be placed directly on the bedding material with the bell end of the pipe facing upstream. Larger diameter pipe should be supported in place with a lifting hook or sling with the bell end of the pipe facing upstream until the jointing operation has been completed.

If the pipe bedding material is properly compacted to grade, no adjustment of the pipe grade should have to be made after the jointing process has been completed. Sometimes it may be necessary to lay large diameter pipe above the design grade and use the impact force and weight of the pipe to bring it to grade. Care must be used, however, to assure uniform support under the entire length of pipe.

3.732 Joining of Pipe

The method of joining pipe will vary with the type of joint. Most pipes for sanitary wastewater collection systems are furnished with a bell on one end, a spigot on the other end, and a resilient type of gasket to make the joining of the bell of the downstream pipe with the spigot of the upstream pipe watertight. Most resilient gaskets are in the form of an O ring sealed in a groove on the spigot or of mating rings precast in the bell and on the spigot. The basic method of joining pipe with resilient joints is:

1. Clean off the bell and spigot,
2. Lubricate the gasket and seat on the pipe as prescribed by the manufacturer,
3. Guide the spigot end of the pipe into the bell,
4. Push or pull the pipe into place,
5. Inspect the joint for proper seating of the gasket, and
6. Check the alignment and grade of pipe.

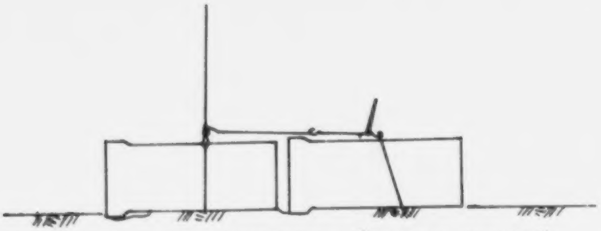
When pipe up to 10 inches in diameter is laid in a trench, the joining can usually be done by hand. When pipe larger than 10 inches in diameter is laid, a mechanical method is used to either push or pull the pipe and gasket into place. If the pipe is pushed into place, the pushing force should be applied to the face of the pipe by the use of blocking to prevent damaging the pipe. The pushing force can be supplied by a bar used as a lever with one end shoved into the trench bottom or by the bucket of a backhoe. Larger diameter pipe is usually joined by the use of a cable and winch either placed along the top of the pipes to be joined or within their interior. Care must be used to prevent pulling the previously laid pipe apart at its joint. Three methods of joining sewer pipe with resilient types of joints are illustrated in Figure 3.38.

Manufacturers of pipe with other than bell and spigot joints will furnish instructions on joining their pipe.

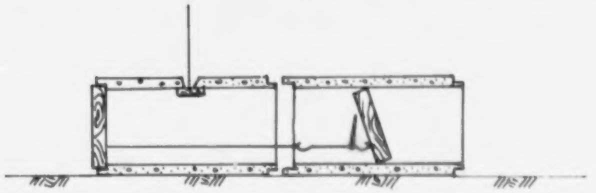
3.733 Protection of Pipe

Once the sewer pipe has been laid to a true grade and alignment, it should be protected from displacement or breakage until the trench is backfilled. This protection is particularly important with respect to smaller diameter and rigid types of pipes such as concrete and vitrified clay pipe. Protection can be provided by immediate placement of initial backfill material.

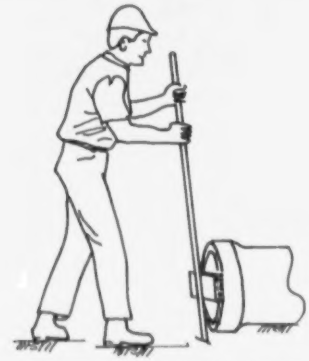
Plug the upper end of the sewer pipe at the end of the work day or whenever pipe laying is to be stopped for several hours. This action will keep material out of the pipe that is difficult to remove once the sewer is completed and also keep out children and small animals. If the possibility exists that the trench could be flooded, do not plug the ends of the pipe completely. A plugged pipe in an open trench may float if the trench becomes flooded and would have to be relaid.



SLING AND OUTSIDE "COME-A-LONG"



LIFTING HOLE AND INSIDE "COME-A-LONG"



BLOCK AND BAR

Fig. 3.38 Methods of pipe joining

(Courtesy of Concrete Pipe Installation Manual, American Concrete Pipe Association)

3.734 Completion of Pipe Bedding

Class A and B bedding require that the backfill be carefully tamped under and around the pipe to a height of 12 inches above the top of the pipe. When bedding smaller diameter pipe, do not displace the pipe by backfilling and compacting on one side and then on the other side. Also, take care not to lift the pipe from its true grade by over-compacting the backfill under the center of the pipe.

Be very careful when compacting backfill over vitrified clay pipe because this pipe is brittle and may be shattered by the use of too heavy a tamper, or by too strong a stroke from a large tamping machine, or by a heavy vibrating compactor.

3.74 Sewer Appurtenances

This section provides an overview of construction procedures for the sewer appurtenances that collection system operators may have to construct occasionally. Construction procedures for the other sewer appurtenances listed in Section 3.33 can be learned by observing construction by contractors and by talking with public works inspectors.

3.740 Construction of Manholes (refer to Figure 3.15, page 53)

After a hole has been excavated for a manhole, the soil must be prepared to provide a suitable foundation. Compact the soil below the manhole base. If the existing soil does not provide a suitable base, gravel or crushed aggregate can be used.

On straight sewers, the pipe is either laid through or terminated at the manhole. Flexible joints are placed in the pipe just outside the area of the manhole base to allow for any differential settlement between the base and pipe. Water stops should be installed where pipes connect to the manhole to prevent infiltration and exfiltration.

The manhole base is made of unreinforced portland cement concrete poured into a basin formed in the bottom of the manhole excavation. The base should be about one foot greater in diameter than the outside of the manhole barrel (refer to Figure 3.15). To shape the channel in the manhole base for smaller diameter sewers, lay in a short section of pipe and pour concrete to the crown (top) of the pipe. The bottom half of the sewer line channel is formed into the base of the manhole. The short section of the upper half of the sewer pipe is broken out after completion of the manhole. If pre-cast manhole barrels are used, a form matching the bottom tongue of the barrel should be pressed into the manhole base and made level before the concrete hardens. The finished channel, however formed, should be U-shaped and as deep as the invert of the pipe.

After the concrete manhole base has hardened sufficiently to support the weight of the manhole barrel and cone (this takes about four hours and hardening can be accelerated with minor sacrifice of strength by the addition of calcium chloride, in an amount not exceeding two percent of the dry weight of the cement content, to the concrete mixture), the preformed groove in the manhole base is filled with cement mortar and the first pre-cast concrete manhole barrel set in place. Successive manhole barrels are set on top of the preceding barrel after the groove in the preceding barrel is filled with cement mortar. Continue in this manner until the combined height of the pre-cast manhole cone and cast-iron frame reaches the planned height of the manhole.

The pre-cast manhole cone section is placed in the same manner as the barrels using cement mortar in the tongue and groove joints. Since a combination of manhole barrels and the top cone and frame seldom make exactly the planned manhole elevations, provisions should be made for possible adjustment with pre-cast concrete grade rings or brick masonry to join the top of the manhole cone to the cast-iron frame at the desired elevation.

In some areas, manhole cones are constructed with brick and mortar instead of using a pre-cast section. A disadvantage of using brick is that the area around the manhole cannot be backfilled immediately because backfilling must wait until the mortar has set.

Fiberglass reinforced polyester manholes of 48-inch round, rib-stiffened barrels are another type of prefabricated manhole. Segments, one third of a circle and four feet long, are glued together to form the barrel. Fiberglass transition cones, sewer pipe connectors, and ladders are provided. The junction with the sewer pipe may be sealed by either attaching a special pipe connector or by packing concrete into the entrance hold and around the entering pipe. Standard cast-iron frames and covers are placed on top of the transition cone. A ledge at the cone top allows room for grade adjustments to be built with iron rings or bricks.

If the manhole is being constructed in an unfinished street, the cast-iron frame and cover are usually left off the manhole and a steel plate is placed over the manhole opening until after the street has been paved. Steel plate covers are more durable than plywood covers and can be located with a metal detector when buried. Then the pavement is removed from around the manhole opening, the steel plate is removed and cement mortar is used to attach the cast-iron frame to the manhole cone or grade rings. The void between the manhole frame and the pavement is then filled with paving material and compacted to grade. For details regarding the raising of manhole lids, see Chapter 7, Section 7.81.

Care should be taken to assure tight joints between the sections of the manhole base, barrel and cone to make them watertight, especially where the groundwater level is above the sewer during any time of the year. An asphaltic mastic joint material is manufactured for use in place of cement mortar when leakage of water through the manhole joints is anticipated.

When constructing a manhole in an easement, it is a good practice to raise the top of the manhole cover about nine inches above normal ground elevation. This will make the manholes visible and less subject to introduction of dirt and surface water through the manhole cover and into the sewer. Manhole covers may be bolted to the frame to prevent unauthorized removal and the dumping of debris into the manhole.

Since a typical pre-cast concrete manhole barrel or cone will weigh about 2,500 pounds, adequate lifting and placing equipment are required, including a crane, or front-end loader, and a "spider" to secure the manhole section to the lifting cable.

Cast-in-place concrete manhole barrels and cones are sometimes used; however, their construction details are beyond the scope of this manual.

3.741 Construction of Cleanouts

Vertical lateral sewer cleanouts at the terminals of lateral and branch sewers (see Figures 3.13 and 3.14, page 51) are constructed with a long radius 1/4 bend of the same diameter and preferably of the same material and jointing as the sewer pipe. They are supported by a compacted granular bedding material (1/4-inch to 3/4-inch crushed aggregate) placed up to the top of the 1/4 bend. Full diameter pipe risers, again preferably of the same material and jointing as the sewer pipe, are placed on top of the 1/4 bend to a height about eight inches below the ground surface. Some agencies prefer the construction of risers using a wye and 1/8 bend for ease of maintenance and the preparation of bedding and placement of backfill.

Hold the vertical pipe riser in place while the trench backfill is compacted. After compaction of the backfill, place a cast-iron frame around the riser pipe with the top set to the ground surface. Pour a portland cement concrete collar around the frame and pipe. Note from Figures 3.13 and 3.14 that a gasket of fibrous material is placed between the concrete collar and the riser pipe so that any settling of the cast-iron frame and concrete collar will not be transmitted to the riser pipe.

3.75 Sewer Trench Backfill and Compaction

Sewer trench backfill, in most instances, is placed around and over the sewer pipe and up to ground surface. The essentials of proper backfilling are (1) protection of the pipe from movement and breakage from impact or crushing from backfill loading, (2) filling of the excavation, and (3) restoration of the ground surface.

3.750 Backfill Materials

The ideal sewer trench backfill material is one that is immediately available, free of any objects that will damage the sewer pipe and easily compacted. Most backfill materials will not be ideal, and compensation for this fact must be made in the backfilling procedures.

Backfill materials are generally classified as native or imported with sub-classifications under each.

NATIVE BACKFILL. Native backfill material, as the name implies, is the material excavated from a sewer trench and, in many instances, is the best material for backfill. This material is immediately available, since it is generally stored alongside the trench, and it is not too difficult to remove any large rocks or broken pieces of pavement that are in the material and that might damage the pipe. However, the native material may not be easily compacted and some judgement must be exercised in determining if and how the material can be suitably compacted, or if it will be better to import backfill material. This is particularly important in the initial backfilling of flexible solid wall plastic pipe and reinforced plastic mortar pipe where compaction is essential to good performance. Soils of clay and silt are particularly difficult to compact to required densities.

In most respects, sand is the ideal backfill material and is used as a standard against which the compactability of other types of backfill material is measured. Laboratory tests can determine the sand equivalency of a representative sample of the backfill material, and a trained inspector can determine the approximate degree of equivalency of other samples in the field.

IMPORTED BACKFILL. Imported trench backfill is quite expensive since there is the cost of hauling and disposing of the native material excavated from the trench combined with the cost of purchasing, excavating and hauling the imported material. For this reason, the use of native backfill material, even with special compactive procedures, should be carefully weighed against the cost of imported material.

Selection of the type of imported backfill material should be based on the ideal qualities listed in this section and modified to balance the cost of the imported material with the cost of obtaining the desired results.

Material being considered for importation should be examined at its source and tests made to determine its sand equivalency.

Suitable imported backfill materials range from crushed aggregate through sand and gravel materials to randomly excavated soil with a minimum sand equivalent of 15. Any material with a lower sand equivalency is probably not any better than the native material.

An important consideration in selecting an imported backfill material is its reaction to surrounding conditions. For instance, one of the disadvantages of using sand backfill is its tendency to move when its side support is removed, such as in subsequent excavations in or near the sewer trench.

3.751 Placement of Backfill

The procedures used for placement of trench backfill, backfill compaction, and surface restoration should provide for protection of the sewer pipe and minimize backfill subsidence (settling) after surface restoration.

PROTECTION OF PIPE. If the class of bedding and initial backfill requires placement of native or imported backfill around the pipe, hand shovel the material from the ground surface to around both sides of the pipe at the same time so that the pressure of uneven backfill will not move the pipe out of alignment. Compact the initial backfill under the bottom of the pipe to eliminate any voids in this critical area of pipe support in accordance with the specifications for the class of bedding (see Figure 3.37). This type of backfilling is generally carried to about 6 to 12 inches above the pipe and must be very carefully placed and compacted to avoid damage to the sewer.

Another, less satisfactory, method of placing the backfill around the pipe is by drifting in the material. In this method the backfill material is pushed into the lower end of the trench by a bulldozer or front-end loader and allowed to slide down the slope that the previously placed material has assumed. The disadvantage of this method is that the initial backfill is not compacted and larger particles of backfill material will slide down the slope faster than the fine material and surround the pipe.

COMPLETING BACKFILL. After initial placement of backfill material around and over the pipe, mechanical equipment, such as bulldozers or front-end loaders, is used to move the backfill material from alongside to inside the trench. If the backfill material particle size is not too large and the trench not too deep, the material may be dropped vertically into the trench. Otherwise, the backfill material should be drifted into the trench as described in the preceding paragraph. Figure 3.39 illustrates a typical backfilling operation.

The method of compacting the backfill material as described in Section 3.752 will influence the method used for placing the material in the trench. For example, if the material is to be compacted in lifts, it will be necessary to drop the material vertically into narrow trenches or to drift and spread with mechanical equipment in wide trenches.

REMOVAL OF TRENCH SHORING. Removal of trench shoring in a safe manner requires coordination with the placement of the trench backfill. The shoring should not be removed until the need for operators to be in the trench no longer exists and the backfilling operation has started.

Hydraulic-actuated aluminum shoring can be decompressed and removed from the topside of the trench completely ahead of placement of the backfill material and for this reason is an excellent type of shoring for most trenches.

When steel screw-type trench or timber braces are used by choice or necessity, closer coordination with placement of the backfill is required. In this instance the backfill should be dropped or drifted to the level of the lowest trench brace. Then after its removal, the trench should be backfilled to the level of each successive brace until all are removed. The vertical shores still will be in place, and it is usually necessary to pull them out with a crane or the bucket of a front-end loader. Backfilling equipment in the vicinity of the trench brace removal operation should be stopped to avoid possible collapsing of the trench walls while a brace is being removed by an operator in the trench.

When either timber or steel sheet piling is used for trench shoring, it may be left in place if its removal will damage the sewer pipe or adjacent facilities. However, the upper several feet of the sheeting should be cut off and removed to avoid interference with surface restoration or future underground construction.

3.752 Compaction of Backfill

Compaction of trench backfill has no beneficial effect upon the performance of a sewer. The load on a sewer pipe increases to a certain extent as the backfill material is made more dense by compaction. However, it is essential that trench backfill material be well compacted to avoid later settling that could cause damage to utilities crossing the trench or to structures adjacent to the trench. Subsidence could also cause depressions in the overlying street surface; these would require repaving.

The following sections outline the more common methods of compacting backfill material and measuring their effectiveness.

WATER COMPACTION. Jetting trench backfill material with water is one common method of compaction. When the type of backfill material is suitable, this type of compaction is simple, quick, and economical, but still inferior to mechanical compaction. Generally, backfill material with a sand equivalent of less than 15 percent is not suitable for compaction by water jetting.

Equipment for compaction by water jetting consists of 1-1/2 to 2-inch diameter jet pipe long enough to reach to within two feet of the top of the sewer pipe, hose, and a water supply that will produce a 10 to 15 pounds per square inch pressure at the jet nozzle.

Fig. 3.39 Placing backfill

Push the jet pipe into the backfill with the water running until the nozzle is within about two feet of the top of the pipe. Leave the nozzle in place until water reaches the trench surface. Usually the backfill material will stop subsiding about the time water reaches the surface. When water reaches the surface, move the jet pipe about ten feet up the trench and to the opposite side of the trench; repeat the jetting operation. In a wide trench it may be necessary to shorten the distance between the jetting locations. As a rule, it is better to over-jet rather than under-jet. Figure 3.40 illustrates compaction of a trench backfill by water jetting.

If a trench is deeper than 12 feet, the backfill material should be placed and compacted in two or more lifts or layers before filling and compacting the remainder of the trench.

Vibrating equipment is sometimes used along with the water jetting to develop a greater compaction of the backfill.

Another way to compact backfill is to flood the filled trench with water. This method is less satisfactory than water jetting and is not often used. The procedure is to make a shallow ditch along the trench backfill and flood it with water. At the same time, rod the backfill material from top to bottom until the required compaction is obtained. The rod is a 2- to 2.5-inch pole that is used to push the mud and water on the surface to the bottom of the trench and to fill the air voids in the backfill material.

The disadvantages of compaction with water jetting or flooding are: (1) these methods are not suitable for all types of soils; (2) they are subject to wide variations of results depending on procedures used; (3) the trench surface cannot be restored or pavement replaced until the trench backfill has dried out; and (4) because the amount of compaction is less than that obtained by mechanical methods, there may be later subsidence and pavement failures.

MECHANICAL COMPACTION. Properly performed mechanical compaction of trench backfill should be used when later subsidence of the backfill could result in expensive or

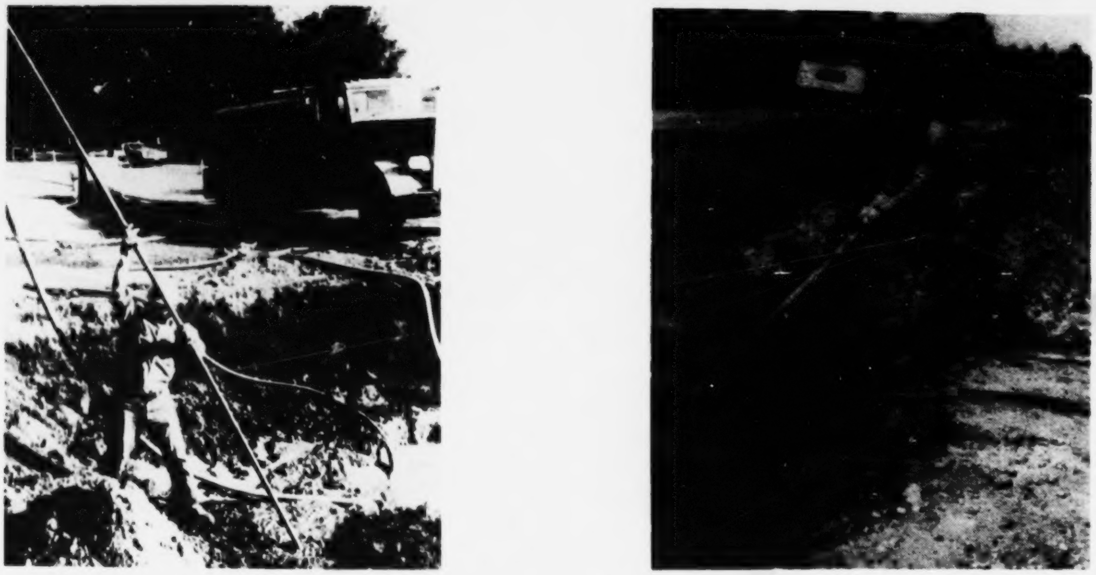


Fig. 3.40 Compaction of trench backfill by water jetting

inconvenient street surface restoration or damage to adjacent structures.

Equipment for mechanical compaction of backfill material consists of hand-held air tampers; hand-held, gasoline-driven impactors; plate vibrators; vehicle-mounted impactors; and vibrating rollers.

When mechanical compacting equipment is used, the backfill material has to be placed in lifts or layers matching the compacting capabilities of the equipment used. For instance, four-inch lifts are about maximum for hand-held compacting equipment; whereas lifts up to three-feet thick can be compacted with vehicular types of impactors, but these impactors can cause pipe damage if not used properly.

The moisture content of the backfill material to be compacted is very important. Material with insufficient moisture will tend to bulk and rebound under the compactive effort; whereas material with too much moisture will be moved away (pumped) from the compactive effort and displace the adjacent material. An approximate method to determine the proper moisture content is to add water slowly to a dry sample in your hand until it can be formed into a compact ball.

Compaction of narrow trenches requires the use of hand-held equipment and numerous shallow lifts. For this reason, an economical alternative to mechanical compaction of native material may be the use of imported backfill material that does not need to be compacted or can be compacted by jetting with water.

Mechanical compaction becomes more practical in wide trenches where vehicular compaction equipment with deeper lifts of backfill material can be used to produce the required compaction at a reasonable cost.

Quite often water jetting and mechanical compaction are used together to compact trenches excavated in paved area. When this procedure is used, the backfill material is first jetted and then the trench refilled to the paved surface with the rock material to be used for the base of the repaving. The trench is allowed to "dry" for several days. After drying, a vehicular impactor is used to compact the surface of the trench just prior to repaving.

The main disadvantages of mechanical compaction of trench backfill are: (1) length of time required; (2) maintenance of shoring during compaction in lifts; (3) excessive impact can damage pipe; (4) high costs.

MEASUREMENT OF COMPACTION. The amount of compaction that has been obtained in trench backfill material is determined by measuring the density of the "in-place material" in pounds per cubic foot and comparing it with the maximum obtainable density of the same material under ideal conditions. This is called the relative compaction since the test relates the actual density to the maximum obtainable density.

Determining the in-place density of the backfill material after compaction and the maximum obtainable density of the backfill material is a complicated procedure requiring the services of a well-equipped and staffed soils testing laboratory using standard procedures developed by state departments of public works and the American Society for Testing and Materials.

A common requirement is for the compaction of the backfill material in the lower area of the trench to 90 percent of maximum and the upper three feet to 95 percent of maximum.

3.753 Surface Restoration

The final operation in constructing a sewer is restoring the ground surface disturbed by the construction process. Usually the surface is restored to its original condition.

IN EASEMENTS. Surface restoration over sewer trenches in easements usually requires removal of excess dirt and rocks that may have been excavated from the trench, followed by bringing in top soil in cultivated areas and replanting in landscaped areas.

IN PAVED AREAS. Surface restoration over trenches in paved areas requires the compaction of the trench surface by mechanical means, re-excavation of the backfill material (if compaction does not produce the required depth) to the subgrade of the pavement, and repaving with materials similar to the original pavement.

3.8 SEWER CONSTRUCTION INSPECTION AND TESTING

3.80 Need for Sewer Construction Inspection and Testing

Imagine what could happen if a new wastewater collection system was put into service and something was wrong with the system. A disastrous mess could develop and repairs would be very difficult. *PROPER TESTING* and *INSPECTION* of a new sewer system *BEFORE* placing it in service can prevent serious problems from developing and avoid considerable grief.

New wastewater collection system construction materials and procedures are inspected by a public agency-owner to:

1. Assure compliance with the plans, specifications, and safety regulations governing the work.
2. Alert the design engineers to any modification of plans required to meet unexpected conditions found during construction.
3. Minimize need for future maintenance of wastewater collection system by assuring close compliance with plans, specifications and good construction practices.
4. Provide a record of the construction progress and "as-built" plans of the wastewater collection system that is buried, but cannot be forgotten. Locating portions of the system in the future can be very difficult and costly without accurate "as-builts" showing the exact location of facilities in the system.

The *PUBLIC WORKS INSPECTOR'S MANUAL* written by Silas R. Birch, Jr., Inspector of Public Works, City of Los Angeles, California, and published by Building News, Inc., 3055 Overland Avenue, Los Angeles, California 90034 (price $9.50), provides an excellent reference on the purposes and procedures for inspection of public works construction, including wastewater collection systems.

3.81 Duties of An Inspector

The duties of a wastewater collection system construction inspector, performed under the supervision of a registered professional engineer, are to act as an observer and reporter of materials and procedures used for constructing the system. In small towns or sanitary districts, the inspection may be shared with the design and project engineer.

Any major deviation from the plans, specifications, safety regulations and good procedures for construction of a collection system are accurately reported by the inspector to the project engineer for remedial action. Minor deviations are usually eliminated in the field by conferences between the inspector and the contractor's superintendent of construction.

An inspector should attempt to anticipate field conditions, such as previously undetected utilities or other obstructions, that may require a change in the location of a planned sewer, and submit a prompt report to the project engineer in order to minimize any delays and costs caused by correcting the situation. The inspector must be sure that the installation procedures, materials, and workmanship conform with the project specifications.

Inspectors also must prepare written reports that will

1. Provide a daily measure of construction progress, record compliance with safety regulations, and call attention to any unusual incidents;
2. Provide a monthly measure of completed work that can be used as a basis for progress payments to the contractor;
3. List the final items of work to be completed prior to acceptance of the project by the public agency-owner; and
4. Indicate the location of the buried wastewater collection system, generally submitted in the form of "as-built" plans. Locations should be measured accurately from several permanent surface points to the critical points of the system so that they can be relocated easily. Also show on "as-builts" the locations of all other underground utilities and facilities that are exposed during construction. Knowing the distances of other utilities from the sewer line is very helpful when making repairs in the future.

3.82 Qualifications of An Inspector

A sewer construction inspector, in order to adequately perform the duties, should have knowledge of: (1) methods and equipment used in wastewater collection systems; (2) fundamentals of construction surveying; (3) the physical properties, types and uses of sewer construction materials; (4) procedures and equipment used in testing construction materials; and (5) laws, codes, ordinances and standards applicable to public works construction in general and wastewater collection system construction specifically.

A well prepared sewer construction inspector also should have the ability to: (1) read and interpret plans, specifications, ordinances and regulations applicable to wastewater collection system construction; (2) determine if construction materials conform to specifications; (3) keep accurate records, gather data and prepare accurate reports; (4) make simple engineering calculations; and (5) establish and maintain cooperative working relations with those contacted in the course of work, including contractors and general public.

3.83 Inspection and Testing of Construction Materials

Wastewater collection system construction materials should be inspected initially for compliance specifications as close as possible to the manufacturing site. This inspection can minimize the delays and costs resulting from the replacement of rejected materials. In all situations, the materials should be inspected again for damage and defects prior to their installation. Many public agencies and manufacturers use the materials specifications published by the American Society for Testing and Materials (ASTM) as their standards for wastewater collection systems materials. Copies of these specifications can be obtained from the ASTM, 655 Fifteenth Street, NW, Washington, DC 20005.

3.830 Sewer Pipe

Most public agencies rely on the integrity and quality control of the manufacturer of small diameter pipe (up through approximately 24-inch diameter) to insure production of pipe that meets specifications. However, thorough inspection of the pipe should be made after delivery to the job site to detect any damage to the pipe resulting from handling after manufacturing, including loading, transportation and unloading.

On the other hand, most public agencies will send an observer to the plant of the manufacturer of large diameter pipe to observe and certify to the manufacturer's testing of representative samples of pipe for compliance with specifications. As in the case of smaller diameter pipe, large diameter pipe should be inspected after delivery to the job site to detect any damage resulting during the delivery.

Some agencies hire an independent testing laboratory to test and certify that the pipe meets all specifications.

The procedures used in testing the various types of pipe used for sanitary and storm sewer construction are beyond the scope of this manual. For further information on these procedures, references can be made to the publications of the pipe manufacturers and the standards for testing procedures published by the American Society for Testing and Materials, 655 Fifteenth Street, NW, Washington DC 20005.

3.831 Appurtenances

As in the case of small diameter sewer pipe, most public agencies rely upon the integrity and quality control of the manufacturer of collection system appurtenances, such as pre-cast concrete manhole barrels, cast-iron frames and covers for manholes and risers, wyes and tees, to assure compliance with specifications. On-the-job site inspection is used to detect any visible defects missed by the manufacturer or resulting from handling.

3.832 Pipe Bedding and Trench Backfill Materials

An inspector should arrange to have representative samples of sewer pipe bedding and imported trench backfill tested for compliance with the specifications for these materials. Most inspectors are not trained or equipped to perform these tests. However, by comparing samples of materials that meet their specifications with subsequent deliveries, an inspector generally can detect and reject material not meeting specifications.

Information on soil testing procedures can be obtained from the American Society for Testing and Materials and the materials and research departments of most state public works or transportation agencies.

3.833 Portland Cement Concrete

Portland cement concrete used for constructing load bearing structures should be tested with respect to its composition, workability, strength and density. An inspector will use the services of the agency's materials testing laboratory for conducting most of these tests.

3.84 Inspection of Construction Procedures

Proper inspection of the procedures used to construct sanitary and storm sewers using materials meeting specifications will assure production of a wastewater collection system that will function in accordance with the engineer's design and should require the minimum of maintenance.

3.840 Location of Utilities

Be sure utility owners are asked to send a representative (locator) to mark the location of buried utilities in the vicinity of the construction you are inspecting. The importance of and procedure for locating buried utilities was described in Section 3.701.

If the actual locations of the underground utilities are different from those shown on the construction plans and require a change in the location of the proposed sewer, the inspector should immediately notify the project engineer of the location of the utilities and the need for a change of plans.

An inspector also should be familiar with the procedure to be followed protecting a utility from damage if it is exposed during construction. Many utility companies want to have their own employees inspect the utility and restore any protective coating damaged by construction activities. The inspector also should determine that an exposed utility is protected from damage during trench backfilling and compaction operations.

When a sewer is constructed under gas service lines, it is a good practice to advise the utility company when the project is completed and request their inspection of building connections to each service line to determine if any gas leaks have been caused by the construction. Be sure to mark the exact location of other utilities on the "as-built" plans.

3.841 Trench Excavation

The following are the major items that should be inspected for conformity with construction requirements during excavation of a sewer trench:

1. Obtain pictures of nearby private property before starting trench excavation in an easement to avoid having to repair or replace private property such as gardens and sidewalks that were not damaged by the trenching activities,
2. Compliance with the traffic control and other regulations established by a street encroachment permit,
3. Correct line and grade for the trench excavation (refer to Section 3.71 for sewer alignment and grade control),
4. Compliance with trench excavation safety regulations (refer to Section 3.702), and
5. Cleaning of trench bottom and adequate compaction of backfill in any undercut areas to provide a solid base for sewer pipe bedding.
6. Dust must be controlled during trench excavation.
7. Public safety. Provide safe access to residences and businesses. Secure work site at end of day for safety of children and to prevent vandalism.

3.842 Pipe Laying

During the pipe laying operation the following items of work should be inspected:

1. Sewer pipe bedding placed to prescribed depth and grade (refer to Section 3.711).
2. Sewer pipe laid to grade with joints made in accordance with manufacturer's instructions (refer to Sections 3.711 and 3.73). Each sewer pipe in place must be closely inspected for any visible defects such as a cracked bell or an unseated gasket. The gradient of each sewer pipe

should be double checked by placing a spirit level along the top of the pipe barrel.

3. The interior of the pipe should be free of bedding materials, dirt, boards, or other debris that could create problems in the wastewater collection system when it is put into service.

3.843 Construction of Appurtenances

Construction of major wastewater collection system appurtenances should be inspected for the following:

1. Location of wyes and tees in the main and lateral sanitary sewers to provide connections for designated locations of building sewers. Each location must be recorded on the "as-built" plans for future recovery if building sewers are constructed after backfilling the main sewer trench.
2. Manhole bases poured on firm foundation; continuous support under sewer pipes between edge of bases and undisturbed trench bottom; construction of channels to proper width and grade; placement of manhole barrels in vertical alignment with watertight joints; and placement of cast-iron frames and covers at proper grade (refer to Section 3.740 for manhole construction details).
3. Vertical riser bends should be surrounded by compacted aggregate to support the weight of the vertical piping; the vertical pipe insulated from surface loading applied to the frame and cover; and cast-iron frame and cover set to proper grade (refer to Section 3.741 for construction details).

3.844 Trench Backfilling and Compaction

An inspector should check the following aspects of sewer trench backfilling:

1. Placement of backfill material alongside of the sewer pipe in a manner that will not cause lateral or vertical displacement of the pipe.
2. Placement of backfill material in a manner that will not cause heavier material to accumulate around and adjacent to the sewer pipe.
3. Placement of backfill material in lifts and with moisture content matching required compaction method.
4. Compaction of the trench backfill in the manner and amount specified (refer to Section 3.752). The amount of compaction obtained by the compactive efforts are determined by relative compaction tests beyond the scope of training and equipment provided most inspectors. However, an inspector along with the project engineer should arrange for an appropriate number of such tests to determine the adequacy of compaction. An inspector should develop by experience a feel for the amount and type of compaction obtained.
5. After backfilling is completed, visually inspect the lines for leaks, displaced pipe, and other signs of damage.
6. If time or costs do not allow TV inspection of the entire newly constructed sewer line, the design engineer, the inspector, and a maintenance operator may each identify portions of the job they believe should be given a final inspection with TV. Inspection procedures using TV equipment are outlined in Chapter 5, "Inspecting and Testing Collection Systems."

3.845 Surface Restoration and Cleanup

Surface restoration should not be started until the inspection and testing of the newly constructed sewer line has been completed. If the surface of a trench is paved or landscaped prior to inspection and testing and defects are found requiring the relaying of portions of the sewer line, the surface restoration will have to be torn up and replaced at a significant additional cost.

The manner and procedure for surface restoration will vary with the surface conditions existing prior to construction of the wastewater collection system. The purpose of restoration is to return the surface as nearly as possible to its original condition. In many instances the surface will be under the jurisdiction of an agency apart from the public agency-owner of the system and the type of, and procedure for, surface restoration will be specified by that agency. The inspector must require the contractor to follow these specifications. During surface restoration the inspector should have manholes or other sewer openings covered and protected from the introduction of surfacing materials and the entrance of storm water runoff which may carry silt and debris into the newly constructed sewer.

Inspection of the final cleanup of the construction area is important since it is the last opportunity to have a contractor complete those jobs left to the end before pulling the last workers off the job. The inspector also should use a list of uncompleted work developed from a final inspection as a guide for the work to be completed before recommending acceptance of a project. Section 3.88 describes the procedures for the final inspection.

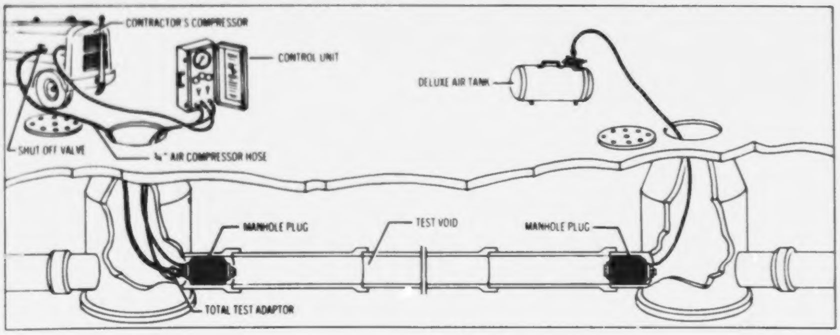
3.85 Air Testing

The main reason for using low pressure air testing for testing sewers is that pressurized air exerts the same pressure in all directions on the pipe during a specific moment in time. The fact that air can leak through a smaller crack than wastewater can be one of the drawbacks of the use of air testing. A properly conducted infiltration or exfiltration test using water will give a true reading of the quality of pipe construction. The problems with using the water test include the time, money and water wastage involved in running these tests. Extreme care must be exercised when specifying and conducting both air and water tests. In steep terrain, air tests are better than water tests because of excessive water pressures created at the lower end of a sewer line. For this reason, air testing is replacing the older and less dependable water pressure testing of wastewater collection systems in many regions.

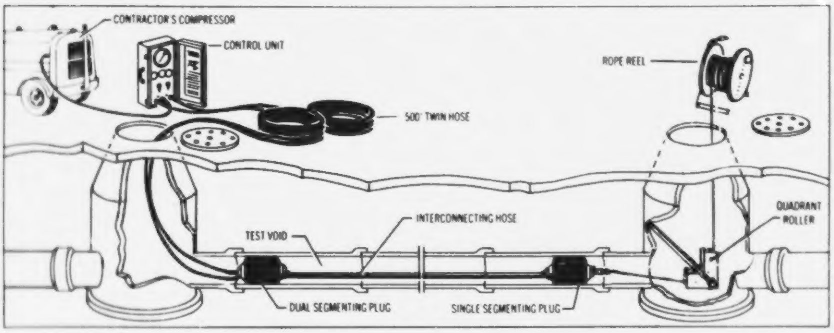
Two typical air test setups for sewer lines and the necessary equipment are illustrated in Figure 3.41.

3.850 Test Pressures

Sewer pipes are usually tested at air pressure around three to five psi above any outside water pressure on the pipe. This outside pressure, which may be caused by groundwater levels that are higher than the pipe, must be known or estimated. The air pressure inside the pipe during testing must be great enough to overcome the water pressure outside the pipe so that air can leak out if there are cracks and holes in the pipe. Be careful air test pressures are not too high, because they could blow out pipe joints or


CONTRACTOR'S COMPRESSOR
CONTROL UNIT
DELUXE AIR TANK
SHUT OFF VALVE
¾" AIR COMPRESSOR HOSE
MANHOLE PLUG
TEST VOID
MANHOLE PLUG
TOTAL TEST ADAPTOR

Manhole to manhole air test.


CONTRACTOR'S COMPRESSOR
CONTROL UNIT
ROPE REEL
500' TWIN HOSE
QUADRANT ROLLER
INTERCONNECTING HOSE
TEST VOID
DUAL SEGMENTING PLUG
SINGLE SEGMENTING PLUG

Segment of pipe air tests.

Fig. 3.41 Typical air test set ups

plugs that can cause injury to personnel or damage to the system.

Where a water table elevation is known and the depth of the pipe below this water table can be measured, determine the test pressure by adding one-half pound per square inch for each foot of water depth above the bottom of the pipe to the test pressure.

?
6FT DEEP?
5PSI
½ LB OR
T.P.= 4PSI

EXAMPLE: A pipe is known to lie at an average depth of two feet below the existing water table of the groundwater and is to be tested to a pressure of 3 psi. If we can increase the test pressure one-half pound for each foot of water above it, or an additional 1 psi, the test pressure for the pipe will be 4 psi.

During the air test, a compressor pumps air into the plugged segment of the sewer and increases the air pressure inside the sewer. This higher pressure (3 psi above atmospheric pressure) is measured with a pressure gage. If leaks are present in the sewer, the air pressure in the sewer will drop back down to atmospheric pressure.

Test pressures for wastewater collection systems are seldom higher than six psi. A diaphragm type of pressure gage with a *LOGARITHMIC SCALE*[16] is considered the best type of gage for testing wastewater collection systems.

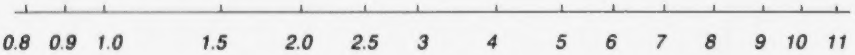
3.851 Volume of Air Required

Further along in Section 3.852, where each method of air testing is covered in detail, required equipment is listed. In all cases, a source of air pressure is required and this is usually provided by an air compressor. An adequate capacity air compressor should be on hand before starting to pressurize a pipeline. Tables 3.7 and 3.8 can provide an estimate of the amount of air required for selected pipe sizes and required test pressures.

First determine the pipe diameter and length of the pipe to be tested. Table 3.7 shows the volume of air in a one-foot length of pipe with the inside diameter indicated. Table 3.8

---

[16] *Logarithmic Scale (LOG-uh-RITH-mick). A scale on which actual distances from the origin are proportional to the logarithms of the corresponding scale numbers rather than to the numbers themselves. A logarithmic scale has the numbers getting bigger as the distances between the numbers decreases.*


0.8
0.9
1.0
1.5
2.0
2.5
3
4
5
6
7
8
9
10
11

shows how much additional air in atmospheres (one atmosphere is approximately 15 psi absolute pressure) must be added to any space to achieve the indicated test pressure. The third column in Table 3.8 indicates the approximate depth of the pipe in feet below the elevation of the groundwater table. The following examples show how to determine air volumes and pressures.

TABLE 3.7 PIPE SIZES AND VOLUMES

Diameter, inches	Volume, cu ft per ft of pipe
4	0.087
6	0.196*
8	0.349
10	0.545
12	0.785
15	1.23
18	1.77
21	2.41
24	3.14
27	3.98
30	4.91
36	7.07
42	9.62
48	12.57
54	15.90
60	19.64

*Sample problem below.

TABLE 3.8 PRESSURE, ATMOSPHERES AND DEPTHS

Test, PSI**	Atmosphere Increase	Water Depth Over Pipe, ft
4	0.2666	0
5	0.3333	2
6	0.4	4

**NOTE: For safety reasons, test pressures should not exceed 6 psi. If there is more than 4 feet of water depth over a pipe and water is not leaking into the sewer, the pipe apparently will not have problems from infiltration or exfiltration.

EXAMPLE 7: 350 feet of new six-inch pipe is four feet below the water table and is to be given an air test.

From Table 3.7, 6-inch pipe has a volume of 0.196 cubic feet per foot of length. Multiply this value by the total length to be tested at one time to get the total volume of the pipe.

$$\text{Pipe Volume, cu ft} = (\text{Table 3.7 value})(\text{Length, ft})$$

$$= (0.196 \text{ cu ft/ft})(350 \text{ ft})$$

$$= 68.6 \text{ cu ft}$$

For an effective 4 psi test with the pipe 4 feet below the elevation of the water table, we will need the 4 psi plus a half pound for each foot of depth, or 2 psi more. This means that our test pressure will be 6 psi (4 psi + 2 psi). For 6 psi, we have to add 0.40 atmospheres to the air that is already in the pipe, or the compressor will have to put 40 percent of the volume of the pipe into the test area.

$$\text{Volume of test air, cu ft} = (\text{Pipe Volume, cu ft})(\text{Table 3.8 Value})$$

$$= (68.6 \text{ cu ft})(0.40)$$

$$= 27.44 \text{ cu ft}$$

From this information, a 2 cubic feet per minute (CFM) at 75 psi compressor will take about three minutes to pressurize the length of pipe to the desired 6 psi. To determine how long a compressor will take to fill a pipe with air to the desired pressure, consult the compressor's operation and maintenance manual prepared by the manufacturer. If the difference in temperature between the air pumped into the pipe and the soil surrounding the pipe is large, consideration may have to be given to this factor when estimating the time it will take to fill the pipe with air. The restrictions or constrictions in the air line and the length of air line between the compressor and the plug often cause sufficient friction losses to significantly increase the time required to pressurize the line being tested.

3.852 Air Testing Procedures

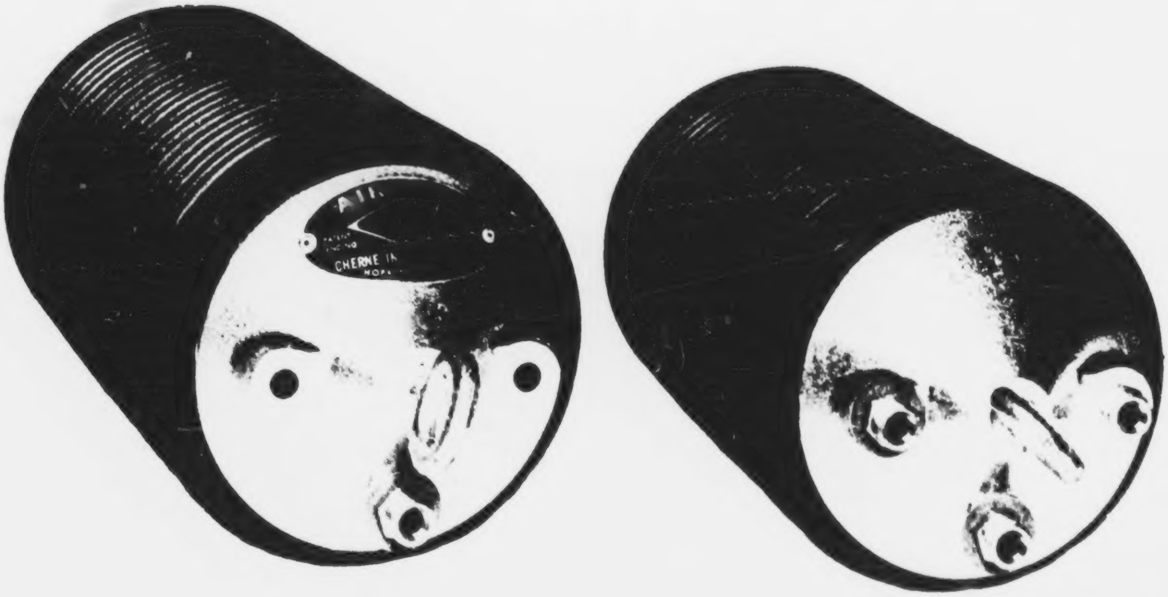
MANHOLE TO MANHOLE. Testing long lengths of pipe is usually limited to new wastewater collection systems that have intentionally plugged building sewers or no service connections.

1. Equipment needed:
   a. Two pipe plugs (Figure 3.42) with taps for connection of pressure gages and air hose. For pipes up to 24-inches in diameter, these may be either mechanical plugs with rubber gaskets or inflatable plugs with rubber boots. For larger than 24-inch pipes, the plugs must either be inflatable bag stoppers or made in two or more pieces in order to be easily positioned in the pipes.

   b. An air compressor of required capacity with a hose to connect to pipe plug. There should be a shut-off valve on the hose connection to the plug. *ALL GAGES AND VALVES MUST BE LOCATED OUTSIDE THE MANHOLE TO AVOID INJURY TO ANYONE READING GAGES OR ADJUSTING VALVES IF A PLUG SHOULD BE BLOWN OUT OF THE PIPE.*

   c. A pressure gage should be connected to the line between the shut-off valve and the pipe plug to indicate pressure behind the plug. *THIS GAGE MUST BE OUT OF THE MANHOLE.*

   d. For safety reasons the air supply line should be provided with an air-safety valve or regulator so that the internal air pressure in the sewer line cannot exceed eight psi.



Used for: 1. Isolating leaks
2. Air testing between manholes
3. Plug for maintenance and repair

Fig. 3.42 Air plugs

(Courtesy of Cherne)

e. A watch to indicate length of test in minutes and seconds is desirable where specified tests are to be made.

f. A garden sprayer filled with soapy water and connected to a long pipe wand. With this device the operator can spray the plugs from outside the manhole.

2. Manpower should be not less than three persons. Where the air compressor does not have an automatic shut-off, one person will have to stand by to shut it down at the start of the test period.

3. Test procedure:

   a. Before testing a sewer, test your equipment. A good procedure is to carry on the equipment truck four-foot sections of PVC pipe of the sizes commonly air tested in the field. Insert a plug in each end of the PVC pipe of the diameter to be air tested and test the air-test equipment. This procedure assures you that your plugs, hoses, gages and equipment are working properly. Record these results so the accuracy of your equipment can't be questioned when performing actual field tests. Take reasonable safety precautions while testing the equipment. For example, stand clear of the pressurized pipe to prevent injury in the event a plug should be blown free.

   b. Insert plugs at each end of the pipe; expand and secure them. Any debris, such as sand or dirt, must be carefully removed from the pipe locations where the gaskets or rubber boots are to make a seal. Do not smear a heavy grease over the outer faces of the gaskets or boots to increase their capacity to seal against any uneven or rough surfaces on the inside of the pipe. The grease will reduce the capability of the pipe to maintain its position. Even with proper bracing, air can by-pass a greased plug.

   c. Before any air hose is connected to the plug at either end of the pipe, firmly block and wedge the plugs into place so that they cannot be pushed or blown out. To understand the need for precaution, realize that the force trying to push the plugs out is equal to the pressure (psi) times the plug surface area (sq in). Table 3.9 gives plugs' surface areas in square inches.

      Realizing the heavy forces that are exerted against the plugs by pressures they are required to withstand, adequate timbers and other bracing material must be selected with care and properly placed so that there is no possible way for the plug to work loose.

      As the plugs are inflated, the air pressure within the plug helps to seal the plug against the pipe walls to hold the plug in place and to prevent air from leaking out around the plug.

   d. After plugs are in place, connect the air hose, inflate or seal the plugs, and then pressurize the sewer to the test pressure.

   e. Supply air slowly to the section of sewer system being tested until the internal pressure is raised to 4.0 (or any other test pressure) pounds per square inch gage pressure (psig). Be careful and do not raise the air pressure much higher than 4.0 psig above the pressure outside the pipeline because it is possible to rupture pipe joints with excessive air pressure. When the test air pressure is reached, close the isolation valve and start the test.

TABLE 3.9 PLUG SURFACE AREAS

Pipe Diameter, Inches	Surface Areas, Square Inches*	If Pressure 5 psi, Force Against Plug, lbs**
4	12.56	63
6	28.27	141
8	50.26	251
10	78.54	393
12	113.10	566
15	176.70	884
18	254.47	1,272
21	346.37	1,732
24	452.39	2,262
30	706.86	3,534
36	1,017.87	5,089
42	1,385.45	6,927
48	1,809.56	9,048
54	2,290.23	11,451
60	2,827.44	14,137

* To calculate surface area, sq in = (0.785)(Diameter, in)^2
** To calculate force, lbs = (Area, sq in)(Pressure, lbs/sq in)

EXAMPLE 8

Calculate the force against each plug if a pipe is 36-inches in diameter and the test pressure is 7 psi.

KNOWN	UNKNOWN
Pipe Diameter, in = 36 in	Force, lbs
Test Pressure, psi = 7 psi	
Surface Area, sq ft = 1,017.87 sq in (from Table 3.9)	

Determine force against plug.

Force, lbs = (Test Pressure, psi)(Surface Area, sq in)

= (7 lbs/sq in)(1,017.87 sq in)

= 7,125 pounds

How would you like to be clobbered by a force of 7,125 pounds?

CAUTION: NEVER ALLOW ANY PERSON TO ENTER A MANHOLE WHILE AIR IS BEING FORCED INTO A PIPE WITH PLUGS IN PLACE OR WHEN ANY PRESSURE REMAINS BEHIND PLUGS.

f. After an internal pressure of 4.0 psig is obtained, allow at least two minutes for air temperature to stabilize, adding only the amount of air required to maintain the 4.0 psig.

g. After two minutes, disconnect the air supply and when the air pressure in the sewer system has decreased to 3.5 psig, start a "stop watch" and stop it when the pressure decreases to 2.5 psig.

h. Compute the allowable time for a decrease in pressure from 3.5 to 2.5 psig using each of the two formulas below.

$$tQ = \frac{0.022}{Q}(d_1^2L_1 + d_2^2L_2 + d_n^2L_n)$$

$$tq = \frac{0.085}{q}\left(\frac{d_1^2L_1 + d_2^2L_2 + d_n^2L_n}{d_1L_1 + d_2L_2 + d_nL_n}\right)$$

Where: tQ = allowable time for decrease in pressure from 3.5 to 2.5 psig in seconds.

tq = same.

Q = 2.0 cubic feet per minute of air loss.

q = 0.0030 cubic feet per minute of air loss per square foot of internal pipe surface.

d = diameter in inches of sewer pipe in section of system being tested.

L = length of sewer pipe being tested.

i. Compare measured time for the air pressure to decrease from 3.5 to 2.5 psig and if it is greater than the lesser of the two allowable times computed from the formulas, the section of sewer system has passed the air test. Experience indicates that infiltration of groundwater into the section of a sewer system passing the low pressure air test will be less than 200 gallons per day per inch of pipe diameter per mile of sewer.

For example, assume an air test is conducted on a section of sewer system containing 400 feet of 8-inch diameter main sewer line and 360 feet of 4-inch diameter building sewer line and the measured time for the air pressure to decrease from 3.5 to 2.5 psig is 225 seconds. Does the section of the collection system pass the air test?

$$\begin{aligned} tQ &= \frac{0.022}{Q}(d_1^2L_1 + d_2^2L_2) \\ &= \frac{0.022}{2}(8^2 \times 400 + 4^2 \times 360) \\ &= 0.011\ (25{,}600 + 5{,}760) \\ &= \underline{\underline{\text{345 seconds}}} \end{aligned}$$

$$\begin{aligned} tq &= \frac{0.085}{q}\left(\frac{d_1^2L_1 + d_2^2L_2}{d_1L_1 + d_2L_2}\right) \\ &= \frac{0.085}{0.0030}\left(\frac{8^2 \times 400 + 4^2 \times 360}{8 \times 400 + 4 \times 360}\right) \\ &= 28.33\left(\frac{25{,}600 + 5{,}760}{3{,}200 + 1{,}440}\right) \\ &= \underline{\underline{\text{192 seconds}}} \end{aligned}$$

Since the measured time of 225 seconds is greater than the lesser of the allowable times (192 seconds), the section of the collection system passes the air test.

If you do considerable air testing, tables indicating allowable air losses or times for pressures to drop will be most helpful.

j. If the test fails, there is a chance that one or both of the seals made by the plugs may be defective. To determine if this is a fact, *THE PRESSURE IN THE TEST AREA IS RELEASED COMPLETELY.* A person using a garden spray full of soapy water with a long pipe wand can spray the plug from outside the manhole. Apply liberal amounts of the soap suds to the seats and connections of the plugs. Be sure the bracing against the test plugs is secure. Repressurize the test section slightly. Inspect for leaks. *BE SURE TO KEEP OUT OF THE WAY OF THE PLUG IF IT SHOULD BREAK LOOSE.* If the gaskets or boots are not properly seated and leak-tight against the

pipe wall, depressurize the plugs and re-seat them. Continue testing in this way until you achieve an air-tight seal.

k. When the air test is completed, lower the pressure in the test section before deflating either of the pipe plugs.

l. Once the test section has lost its air pressure, remove the bracing or cribbing and take out the plugs.

SEARCH FOR SPECIFIC LEAKS. Where a pipe is known to have leaks, or where a pipe in service is connected to unplugged building sewers, these small sections are tested with remote inflation plugs. In this operation, two inflatable plugs of special design are attached to each other with a specific length of chain or steel cable (Figure 3.41). The plugs are pulled through the pipe with a rope and hand winch and stopped at each section equal to the distance between them for a test of the isolated pipe section.

1. Equipment required for this type of testing will include all of the following:

   a. An air compressor of adequate size, but usually not as large as that required for testing long lengths of pipe.

   b. An air pressure control console. This console must have two air pressure regulators, one for controlling the inflation pressures of the boots of the two plugs and one for controlling the test pressure to be injected between them. The control console must also have valving to:

      1. Inject or release the air pressure in the plug boots to isolate the section of pipe being tested.
      2. Inject air pressure into the space in the pipes between the plugs.
      3. Isolate the area between the plugs with a pressure gage showing this pressure and indicating any changes in it over a specified time period.
      4. Release the pressure between the two plugs and then the plug pressure before moving to a new test section or removing the plugs from the sewer.

   c. Two plugs with inflation boots that are properly sized for the pipe to be tested. One of these plugs must have at least one through plug air attachment.

   d. Three air hoses are generally used for greater speed, but two may be sufficient. One hose is used to inflate the boots of the plugs and the other hose is used to inject air to develop the test pressure between the plugs. A third hose may be used to measure the pressure in the test space between the plugs and to release the test pressure through a valve when the test at that location in the pipe is completed.

   e. Two winches to pull the plugs and hoses through the pipe to be tested. One winch is installed at each end of the sewer line to be tested so if you go too far down the line while changing plug position, you can pull the plug and hoses back to position them properly for the next test.

   f. A distance marker system, usually a movable spring clamp on the pull rope and stakes or marks on the pavement. Many winches have a footage counter on the cable which records the distance.

2. Manpower requirements are at least two persons plus support crew to direct traffic or provide other necessary assistance. One person operates the control console and records the test results. The second person moves the plugs with the winch each time a test is completed. A third person must be available whenever anyone must enter a manhole.

3. Prior to the testing of any pipe by this method, the sewer line should be thoroughly cleaned to remove any sand, silt, or other debris which may prevent the inflatable plugs from passing through the line and making a good seal against the pipe wall. The use of a high velocity cleaner or balling as described in Chapter 6 are methods used for cleaning sewer lines prior to testing. Old sewers or sewers with a history of stoppages should be inspected by closed circuit television as described in Chapter 5, after they have been cleaned to be certain that there are no obstructions (protruding taps or offset joints) that may prevent the movement of the air test plugs.

4. In operation, the plugs are put into the line and pulled until the rear plug is just inside of the pipe at the starting manhole.

   a. Inflate the plugs to isolate the pipe area between them.

   b. Inject the desired test pressure into the area. The pressure gage measures the pressure between the plugs. Pressures used for testing should generally conform to those listed in Table 3.8.

   c. The length of the test should be established on the basis of one second for each cubic foot of space between the two plugs.

   d. When a leak is detected, there is a possibility that one of the boots is not seated properly. To attempt to remove an object or bit of debris which may obstruct the boot's contact with the pipe wall, deflate boots while there is pressure between them. This may tend to blow debris out of the area of boot contact. Be extremely careful that no one will be hit by flying debris. Also be sure there is *NO SLACK* in the line between the boots or the boots could be severely damaged.

e. Retest the same area. If a leak is still detected, record the fact and the rate of leakage as "slow," "moderate," or "rapid." Records must include the pressure drop per minute, diameter of pipe, length of pipe, location and date tested.

f. Deflate the plugs and move them to the next test section.

5. Keeping a good record of footages is extremely important in this type of operation. Each test location and the results must be properly and accurately recorded.

a. The distance between the two test plugs should be established and firmly fixed before starting the test. Measure this distance from the inside sealing surfaces or the inside end of one plug to the inside end of the other.

b. To test a section of pipe, the crew leader should review the available information on the pipe to be tested so as to select the areas to be tested and to determine the length of each test section. The inside distance between plugs is usually set at 3-feet, 6-feet, or 9-feet plus three to six inches, depending on the distance between joints and the number of joints to be tested each time. When moving the plugs through the pipe, each move should be exactly the distance between the plugs or a little less.

c. To select the distance between the plugs before starting the run, the supervisor or foreman should estimate whether the pipe to be tested may have many bad leaks or joints, or if only three or four problem areas are suspected. If every joint is suspected as the location of a possible leak, limit the distance to only one pipe section or less and test only one joint at a time. Where only a few, if any, joints are expected to be bad, the distance can be increased with proper coupling. Any desired distance, up to the distance between manholes, could be used. Plugs can be connected and pulled through sewers by the use of a chain or cable which is safer than using rods.

d. If a leak is detected by a pressure drop and more than one pipe joint is being tested, deflate the plugs and pull them back a distance equal to one pipe section. Repeat the test. If the leak is still between the plugs, deflate them and move back another pipe section length. Test again. When the leak is lost, the distance to the leak point or joint is then known, because it is the next joint beyond the lead plug.

e. The distance measurement must be maintained by the operator at the pull winch. If the plug assembly must be backed up at any time, do not move the clip on the pull cable until the test of the leak area is completed. The operator may then pull the plugs to their original position, move the clip back to relocate the plugs in the next part to be tested and then pull them into their new position.

If there is any question about the accuracy of the footage, use the lead plug to find the connection to the line being tested. This is done by moving the plug assembly in one-foot increments and testing after each re-location, usually done when the footage record shows the connection would be located in the next test area. When the test area cannot be pressurized, the lead plug will be within one foot of and beyond the connection.

6. The operator at the control console must always be alert to any pressure drop in the plug boots that might indicate boot perforation or leakage. When this occurs, and a boot is damaged by some object in the pipe, it must be immediately removed and repaired or replaced. Never try to test using this method with defective boots.

7. When one of the service connections to the pipe run being tested is between the plugs, the void area (space in pipe between plugs) cannot be pressurized unless the connection is blocked with another plug. The pull winch operator, who is maintaining a record of the footages tested, should be aware of the occurrence of one of the connections ahead of arrival and signal the test equipment operator.

8. Test records and footage records are usually recorded on the map with pencil marks and footage totals.

BUILDING SEWERS. There are several ways to test individual building sewers. The method you select will depend greatly on the conditions you encounter. The paragraphs that follow briefly outline the selection of a method and the proper test procedures.

1. Where a building sewer is laid in a straight line, use two inflatable plugs. Attach one plug to rigid coupled sewer rods so that it may be pushed down the pipe with a hose for inflation at or close to the connection to the lateral sewer. The second plug will have a pressure gage and a connection for air to be passed through it from another hose.

a. If adequate cleanouts are available, attach the first plug to the rods and push the plug into the pipe to the main or to any desired test distance. Disconnect the last section of the rod so that the rod is just far enough inside the cleanout to install a second plug. Inflate the far plug and push the hose, with closed valve, into the pipe just far enough to permit insertion of the second plug.

b. Insert the second plug, which may be a mechanical type of plug, into the entrance of the pipe; secure it. Pressurize the space between the plugs and proceed with the air test.

c. If the test fails, indicating a leak in the pipe section being tested, pull the far plug back a short distance and re-inflate. Repeat this procedure at short distances until no leakage is indicated. When this happens, it indicates that the far plug has been pulled far enough back and beyond the point of leakage, thus locating the approximate area of the leak.

d. In the event a usable cleanout is not available, the pipe may be excavated and opened for test purposes where desired. A usable cleanout is one which will permit the section of pipe to be tested to be isolated from the building sewer system and its vents and traps.

2. In some testing of this type, two inflatable plugs are

connected to each other with one or more rods and pushed into the pipe section. Once in position, they are used in much the same manner as the two inflatable plugs are used in testing 6-inch or larger pipes, with rods being used to relocate the plugs for each test.

3. Where available, a pipeline pressure grouting unit which has an air testing capacity can be used in conjunction with the television camera (Figure 3.43) to air test individual building sewers.

In operation, pressurized air is pumped into the plugged line from the packer boot inflation air hose (using solenoids in the packer assembly) or through an air pass hose to the air plug in the service pipe. Pressure may be measured in the grouting system or in the pass hose of the plug. Locations of leaks in the service line may be found by moving the air plug on rods and re-inflating and testing at each different location.

3.86 Water Testing

Where conditions are appropriate, a water exfiltration test will provide an accurate test of a new sewer line's ability to convey wastewater without excessive leakage and to resist groundwater infiltration. Any building sewer connections to a

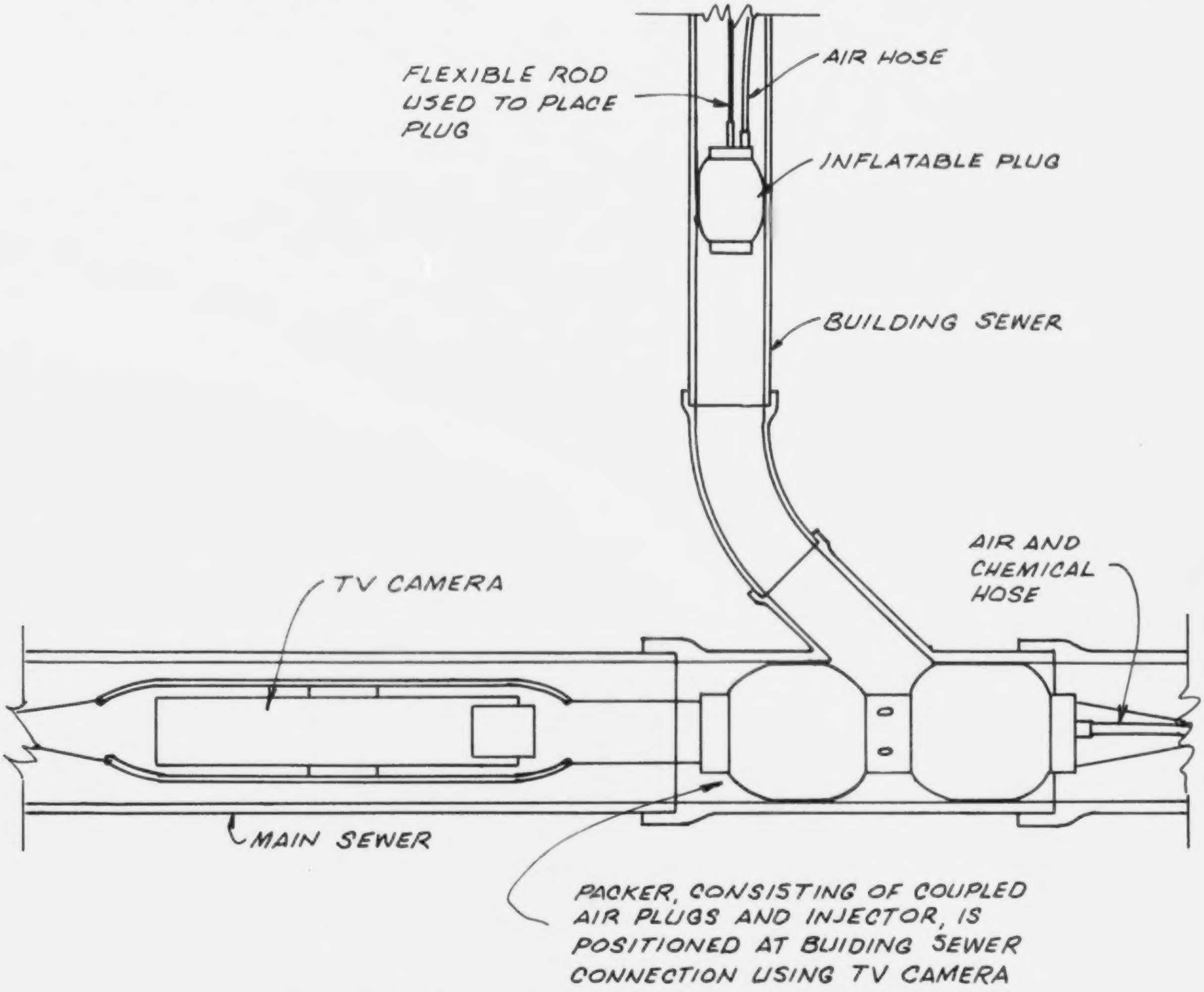

FLEXIBLE ROD USED TO PLACE PLUG
AIR HOSE
INFLATABLE PLUG
BUILDING SEWER
AIR AND CHEMICAL HOSE
TV CAMERA
MAIN SEWER
PACKER, CONSISTING OF COUPLED AIR PLUGS AND INJECTOR, IS POSITIONED AT BUIDING SEWER CONNECTION USING TV CAMERA

Fig. 3.43 Building sewer air testing with TV camera and packer (pressure grounding unit)

sewer line being tested must be plugged. Other limitations on the use of water testing are described in Section 3.85.

3.860 Equipment Needed:

1. Two watertight pipe plugs for the diameter of sewer line to be tested;
2. A source of water that will fill the length of sewer line to be tested in a reasonable period of time (a water truck or fire hydrant and hose); and
3. A tape measure and stop watch.

3.861 Test Procedures:

1. Plug the downstream end of the sewer line to be tested at its inlet into a manhole and plug the inlet sewer at the upstream manhole.
2. Fill the upstream manhole with water to a point four feet above the invert of the manhole channel, or four feet above the average depth of groundwater above the sewer line.
3. Mark the appropriate height of water in the manhole at the start of the test and record the time in hours and minutes.
4. Allow the water to drop two feet and record the elapsed time, or wait 120 minutes and mark the height of water at the end of that time.
5. Measure the diameter of the manhole at the high and low water marks and compute the volume of water that escaped (exfiltrated) from the sewer line in gallons.
6. Divide the loss of water by the time in minutes between the start and finish of the test to compute the rate of water exfiltration in gallons per minute.
7. Multiply the loss of water by 1440 minutes per day to obtain gallons per day lost. Divide this amount by the diameter of the pipe in inches and the length in miles of the sewer line being tested to determine the rate of water exfiltration in gallons per day per inch of diameter per mile length of sewer line. The acceptable rate of water exfiltration from a sewer line is approximately 450 GPD/in/mi, or less.
8. Remove the downstream plug, exercising care with respect to the rapid flow of water that will occur in the sewer line when the test water is released. Then remove the upstream plug. If the water used in the test is to be reused for the next downstream test section, install another plug at the downstream end of the next test section before releasing water from the bottom plug of the upstream test section.

EXAMPLE 9:

Compute the rate of water exfiltration from 400 feet of 8-inch diameter main sewer line and 300 feet of connecting 4-inch diameter building sewers when the water level in the upstream 4-foot diameter manhole drops 4 inches in 120 minutes.

KNOWN

Diameter, in = 8 in
Length, ft = 400 ft
Diameter, in = 4 in
Length, ft = 300 ft
Manhole D, ft = 4 ft
Manhole Drop, in = 4 in
Time, min = 120 min

UNKNOWN

Exfiltration, GPD/in/mi

1. Calculate the volume of water exfiltrated (lost) during the test.

   NOTE: Surface Area, sq in = 0.785(Diameter, in)^2

$$\text{Volume, gal} = (\text{Area, sq ft})(\text{Drop, ft})(7.48\ \text{gal/cu ft})$$

$$= \frac{(0.785)(4\ \text{ft})^2(4\ \text{in})(7.48\ \text{gal/cu ft})}{12\ \text{in/ft}}$$

$$= 31.3\ \text{gal}$$

2. Determine the water lost due to exfiltration in gallons per day.

$$\begin{array}{c}\text{Exfiltration}\\ \text{Rate, GPD}\end{array} = \frac{(\text{Volume, gal})(60\ \text{min/hr})(24\ \text{hr/day})}{\text{Time, min}}$$

$$= \frac{(31.3\ \text{gal})(60\ \text{min/hr})(24\ \text{hr/day})}{120\ \text{min}}$$

$$= 376\ \text{GPD}$$

3. Calculate the exfiltration in gallons per day per inch of pipe diameter per mile of pipe length.

$$\begin{array}{c}\text{Exfiltration}\\ \text{GPD/in/mi}\end{array} = \frac{\text{Exfiltration Rate, GPD}}{(\text{Diameter, in})(\text{Length, mi})+(\text{Diameter, in})(\text{Length, mi})}$$

$$= \frac{376\ \text{GPD}}{(8\ \text{in})(400\ \text{ft}/5280\ \text{ft/mi})+(4\ \text{in})(300\ \text{ft}/5280\ \text{ft/mi})}$$

$$= \frac{376\ \text{GPD}}{0.61\ \text{in/min} + 0.23\ \text{in/mi}}$$

$$= 448\ \text{GPD/in/mi}$$

The sewer line in this example is acceptable since its exfiltration rate is less than the acceptable rate of 450 GPD/in/mi.

If a sewer line does not pass the water exfiltration test, the search for specific leaks is usually conducted with air pressure as described in the preceding Section 3.852.

3.87 Mandrel Test

After placement and compaction of trench backfill and prior to restoration of the surface, all new sewer lines constructed of flexible types of pipe should be tested with a mandrel to measure for deflection and joint offsets.

The mandrel testing device (Figure 3.44) is a rigid cylindrical plug tapered on each end with a diameter equal to 95 percent of the average diameter of the pipe to be tested. The plug has pulling rings at both ends, to which pulling and tag lines are attached. Either or both the pulling and tag lines are marked so that the distance that the mandrel has been pulled into a sewer can be determined.

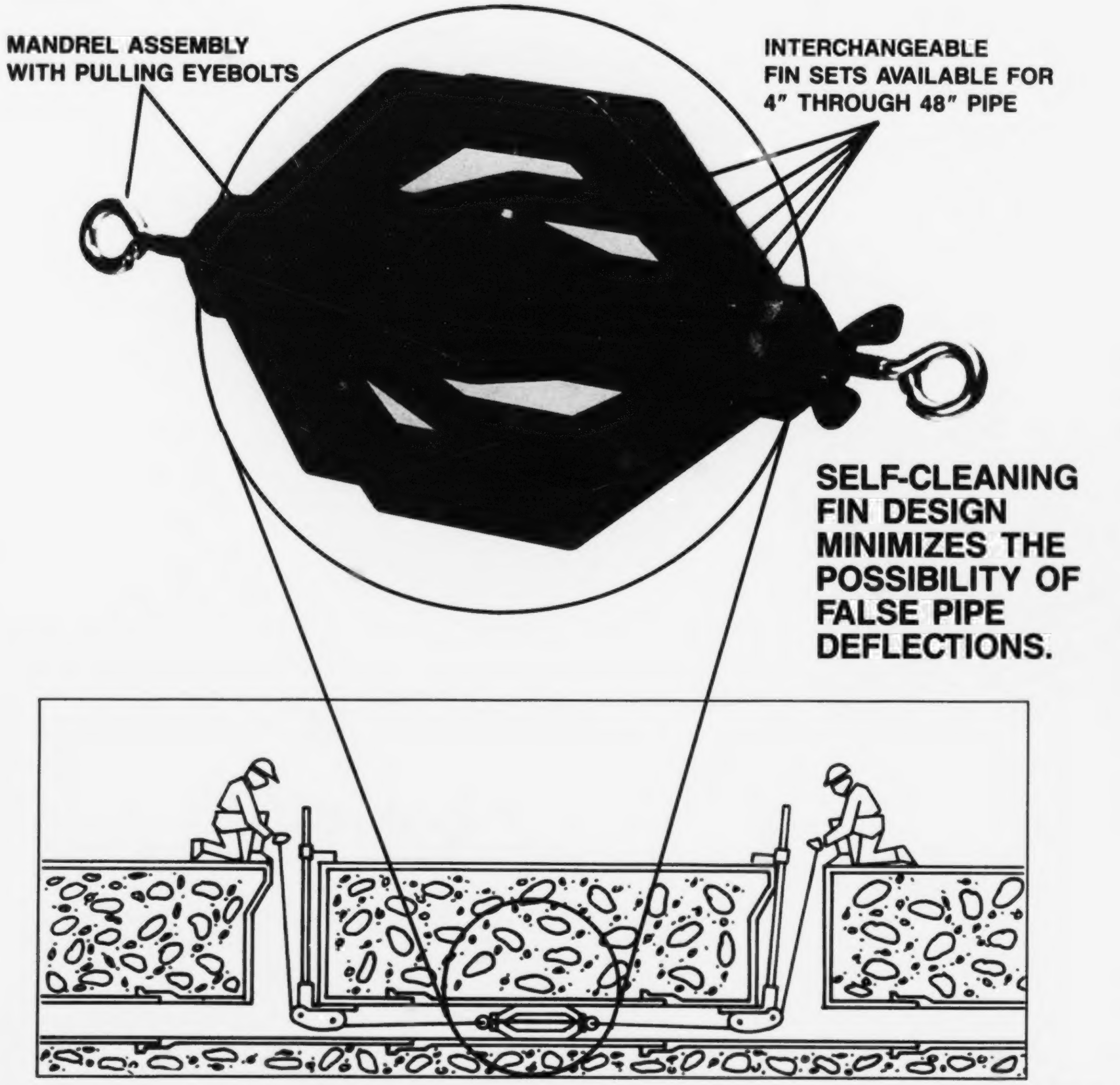
The mandrel test is conducted by pulling the test device through a completed sewer from manhole to manhole. The mandrel device will not pass through a flexible type of pipe that has been deflected beyond five percent of its diameter, if a rigid type of pipe has been crushed, if a joint is offset more than five percent of the pipe diameter or if a building sewer connection is protruding into the main line. The location of the obstruction can be determined by use of the distance markings on either the pulling or tag line. The pipe must be re-excavated and the obstruction removed.

3.88 Final Inspection

If the inspection of each phase of the construction has been thorough, the final inspection of a wastewater collection system construction project should serve as a final check on the small items of uncompleted work remaining, particularly with respect to surface restoration and cleanup, to make the project acceptable to the public agency-owner.

Agencies should have a representative of the department that will be responsible for maintenance of the completed wastewater collection system accompany the inspector at the time of the final inspection for the purpose of pointing out any defects in the system that will cause future maintenance problems. All defects should be corrected before the job is accepted.

In large diameter sewers, the final inspection should include a "walk through" inspection to verify that all the



THE DEFLECTION TEST GAUGE CAN BE EASILY PULLED THROUGH THE PIPELINE.

Fig. 3.44 Mandrel pipe deflection test gauge

(Permission of Cherne Industries, Inc.)

construction tools and debris have been removed. Final visual inspection of sewer lines may reveal standing water and other indications of grade misalignment.

A thorough and detailed list of items of work to be completed should be made at the time of the final inspection with copies being distributed to the contractor and project engineer. A copy of the "as-built" plans should be given to the operation and maintenance organization.

3.89 Construction Records

As previously mentioned, a sewer construction inspector is expected to submit comprehensive reports to the project engineer on the project being inspected. The following paragraphs describe the contents of these reports in more detail.

3.890 Daily Reports

The purpose of a daily report is to provide the project engineer with an overview of the project progress and a source of information for answering questions raised later with respect to conduct of the work.

An inspector should report daily on the weather conditions, amount of work performed on the project, type of soil encountered during excavation of sewer trenches, working conditions with respect to safety regulations, number of workers and type of equipment being used and any significant incidents that may have occurred during the day. Figure 3.45 illustrates a form used for submission of an inspector's daily report. Each agency develops forms to fit their particular reporting requirements and may include such additional items as number of yards of concrete placed and amount of sheet piling driven.

3.891 Monthly Reports

The monthly reports of an inspector generally consist of information that will be used by the project engineer to determine the amount of work completed during the month and the amount to be paid the project contractor for completed work. Figure 3.46 illustrates a form used to submit monthly reports on amount of completed work.

3.892 Building Sewer Locations

In most instances wyes or tees are placed in main sewers for building sewer connections and are buried by the main sewer trench backfill before construction of the building sewer. The inspector must record the location of a wye or tee before it is buried. This is usually done by measuring the distance along the main sewer from the nearest downstream manhole and entering this data on a Building Sewer Location form illustrated by Figure 3.47. The locations must be shown on the "as-built" plans.

Also, since the part of the building sewer constructed in the street is generally buried prior to construction of the remaining part of the building sewer connecting a building to the completed sewer system, it is equally important to record the location and depth of the temporary end of the building sewer. This is usually done by measuring the distance from the end of the building sewer along the street property line to the nearest property corner and measuring the depth of the top of the end of the building sewer below the top of the curb (or surface of the ground if there is no curb). Also the end of the sewer should be located with respect to the curb line (how far inside or outside the curb and the depth from the top of the curb to the top of the sewer). These measurements also are entered onto a Building Sewer Location record. A long piece of wood (2 x 4) placed upright at the end of a temporary sewer is very helpful in the future when attempting to relocate the end of a buried sewer.

The wye, tee, and building sewer location data should be entered directly and immediately onto the appropriate forms.

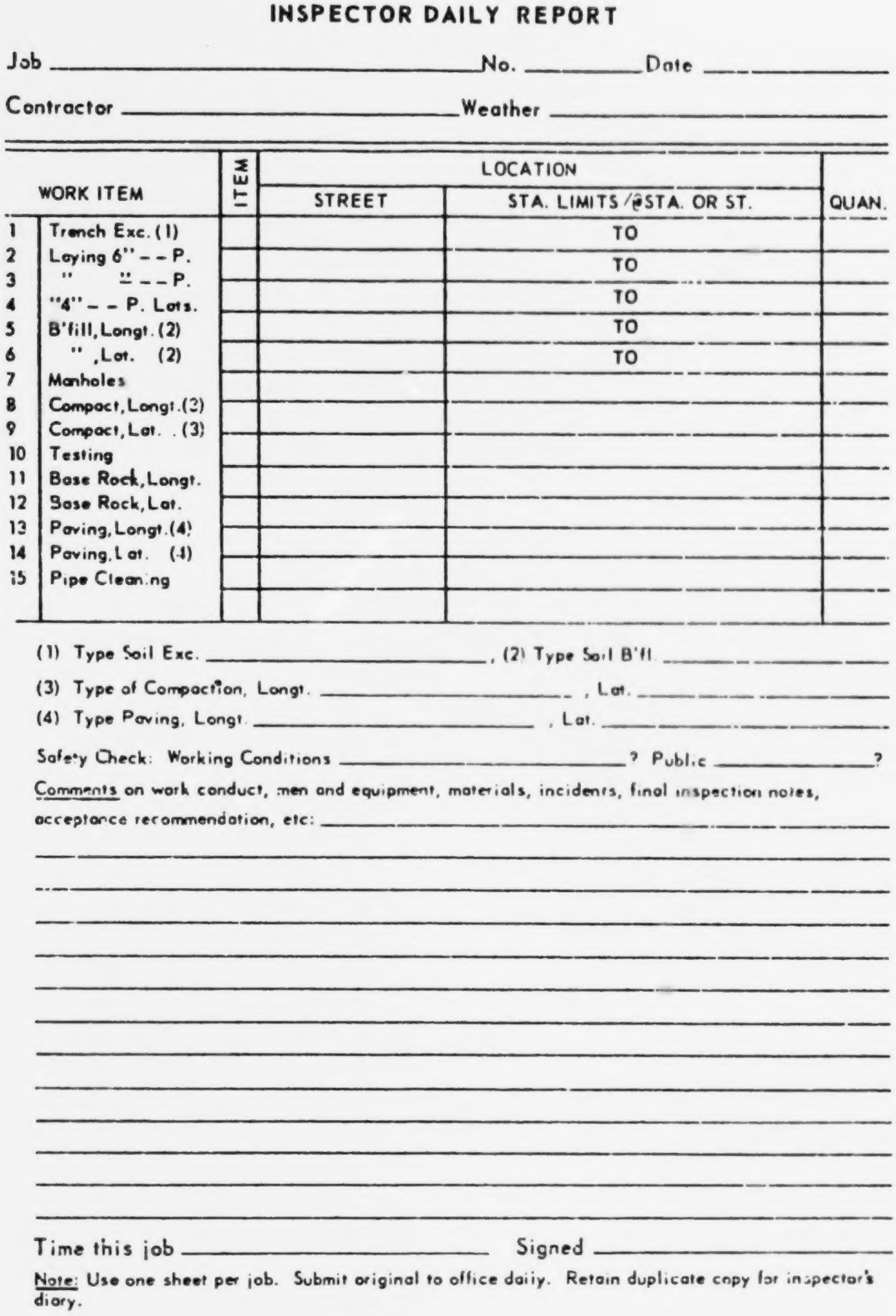
3.893 "As-Built" Plans

At the start of a sewer construction project, the inspector should obtain two sets of the plans for the project and mark one copy "Working Plans" and the other set "As-Built Plans." The working plans are used for on-the-job references and conferences.

The "as-built" plans are for the purpose of recording daily any constructed deviations from the location or depth of the sewer system facilities or any other deviation from the plans. Changes must be recorded as soon as they are found or completed and NEVER put off to another day. Locations of building sewers are commonly shown on the "as-built" plans in addition to recording their location on a "Building Sewer Location Record."

The actual location of the sewer system facilities are usually shown in red pencil on the "as-built" plans using the same scale and style of drafting and notation used in drafting the plans. The "as-built" plans should not be used in place of the inspector's working plans and should be kept clean and readable.

At the conclusion of the project, the "as-built" plans should be submitted to the project engineer in completed form. These plans are either filed directly as an "as-built" record of the project or used by a draftsman to revise the tracings from which the plans are printed. Copies of these plans must be sent to field operators as soon as possible because they must work from them.



INSPECTOR DAILY REPORT

Job ______________________ No. __________ Date ______________

Contractor ______________________ Weather ______________________

WORK ITEM		ITEM	LOCATION		QUAN.
			STREET	STA. LIMITS/@STA. OR ST.	
1	Trench Exc. (1)			TO	
2	Laying 6" – – P.			TO	
3	" " – – P.				
4	"4" – – P. Lats.			TO	
5	B'fill, Longt. (2)			TO	
6	" , Lat. (2)			TO	
7	Manholes				
8	Compact, Longt. (3)				
9	Compact, Lat. (3)				
10	Testing				
11	Base Rock, Longt.				
12	Base Rock, Lat.				
13	Paving, Longt. (4)				
14	Paving, Lat. (4)				
15	Pipe Cleaning				

(1) Type Soil Exc. ______________________, (2) Type Soil B'fl ______________

(3) Type of Compaction, Longt. ______________________, Lat. ______________

(4) Type Paving, Longt. ______________________, Lat. ______________

Safety Check: Working Conditions ______________________? Public ______________?

Comments on work conduct, men and equipment, materials, incidents, final inspection notes, acceptance recommendation, etc: ______________________

Time this job ______________________ Signed ______________________

Note: Use one sheet per job. Submit original to office daily. Retain duplicate copy for inspector's diary.

Fig. 3.45 Inspector's daily report form

REPORT OF QUANTITIES INSTALLED

As of (Date): ____________________

Job: ____________________

Final Report ☐
Progress Report ☐

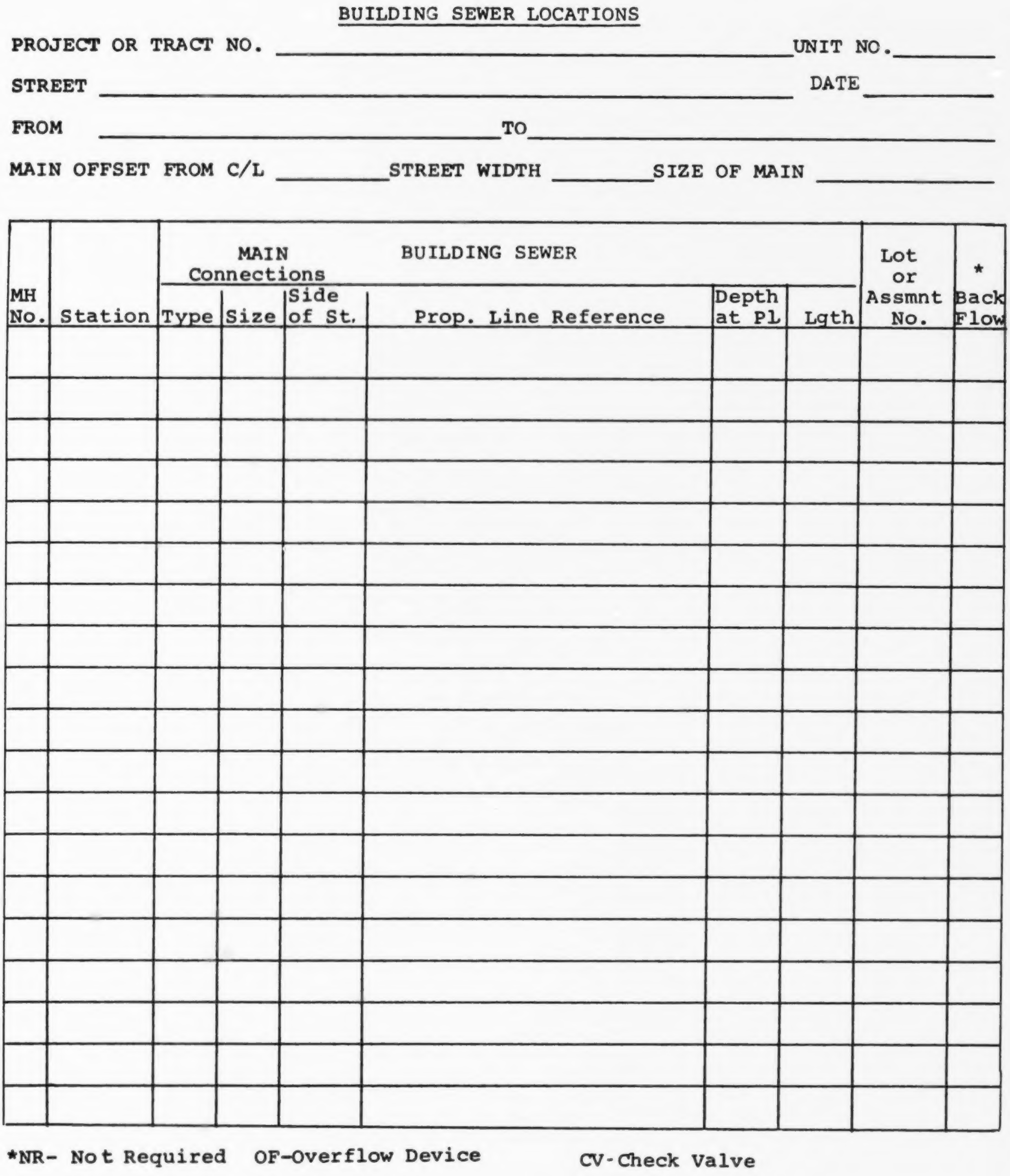
Installer ____________________
Engineer ____________________
Contractor ____________________

STREET	4" B.S.	6" Main	8" Main	___" Main	M.H.	F.I.	Extra Wyes	

____
Inspector

Instructions to Inspector:
Make report in duplicate.
Report progress as of last day of month, when job not complete.
Submit final report when installation has been completed.
Make notes about unusual items.

Fig. 3.46 Monthly report form for completed work



BUILDING SEWER LOCATIONS

PROJECT OR TRACT NO. ______________________ UNIT NO. ________

STREET ______________________ DATE ________

FROM ______________ TO ______________

MAIN OFFSET FROM C/L ________ STREET WIDTH ________ SIZE OF MAIN ________

MH No.	Station	MAIN Connections Type	Size	Side of St.	BUILDING SEWER Prop. Line Reference	Depth at PL	Lgth	Lot or Assmnt No.	* Back Flow

*NR- Not Required OF-Overflow Device CV-Check Valve

Fig. 3.47 Building sewer location form

120

REMEMBER:
"AS BUILT"
PLANS!

The "as-built" plans are also used for preparation of sewer location maps and should also be available to wastewater collection system operators for detailed information if needed for maintenance or repair of a sewer line.

3.9 ADDITIONAL READING

1. *GRAVITY SANITARY SEWER DESIGN AND CONSTRUCTION,* Order No. MOP-FD-50G0, Water Pollution Control Federation, 601 Wythe Street, Alexandria, VA 22314-1994. Price to members, $19.00; nonmembers, $25.00.
2. *WASTEWATER ENGINEERING: COLLECTION AND PUMPING OF WASTEWATER,* by Metcalf & Eddy, Inc., McGraw-Hill Book Company, 1221 Avenue of the Americas, New York, New York 10020. Price, $45.00.
3. *CLAY PIPE ENGINEERING MANUAL,* National Clay Pipe Institute, 101-1/2 South Union Street, Alexandria, VA 22314. Price, $20.00.
4. *CONCRETE PIPE HANDBOOK,* American Concrete Pipe Association, 8320 Old Courthouse Road, Vienna, VA 22180. Price, $27.50.
5. *HANDBOOK OF PVC PIPE-DESIGN AND CONSTRUCTION,* Uni-Bell Plastic Pipe Association, 2655 Villa Creek, Dallas, TX 73234. Price, $40.00.
6. *PUBLIC WORKS INSPECTORS' MANUAL,* Silas R. Birch, Jr., Building News Inc., 3055 Overland Ave., Los Angeles, CA 90034. Price, $9.50.
7. "Air Testing Sanitary Sewers," Sam H. Hobbs and Lloyd G. Cherne, Journal Water Pollution Control Federation, Vol. 40, No. 4, April 1968.
8. "Testing New Sewer Pipe Installations," Roy E. Ramseier, Journal Water Pollution Control Federation, Vol. 44, No. 4, April 1972.
9. *COMMON SENSE IN THE COMMON TRENCH,* by W. Martin "Red" Cass. Available from The Plank Company, 8979 Elk Grove-Florin Road, Sacramento, CA 95624.
10. *ALTERNATIVE SEWER SYSTEMS,* Order No. MFD-120, Water Pollution Control Federation, 601 Wythe Street, Alexandria, VA 22314-1994. Price to members, $16.00, nonmembers, $19.00.

CHAPTER 4

SAFE PROCEDURES

by
George Freeland

Revised by
Rick Arbour

TABLE OF CONTENTS

Chapter 4. SAFE PROCEDURES

Page

OBJECTIVES 112

GLOSSARY 113

4.0 PERFORM YOUR DUTIES SAFELY 114

4.1 VEHICLE AND EQUIPMENT INSPECTION PROCEDURES 114

4.2 DEFENSIVE DRIVING 115

4.3 ROUTING TRAFFIC AROUND JOB SITE 116

4.4 CLASSIFICATION AND DESCRIPTION OF MANHOLE HAZARDS 124

4.40 Confined Spaces 124

4.41 Atmospheric Hazards 132

4.42 Physical Injury 133

4.43 Infections and Diseases 133

4.44 Insects, Bugs and Rodents 135

4.45 Toxicants 135

4.46 Drowning 135

4.47 Summary 135

4.5 SAFETY EQUIPMENT AND PROCEDURES FOR MANHOLE ENTRY 135

4.50 Self-Contained Breathing Apparatus 135

4.51 Safety Harness with Lifeline, Tripod and Winch 137

4.52 Portable Atmospheric Alarm Unit 137

4.53 Ventilation Blower with Hose 144

4.54 Manhole Enclosure 146

4.55 Ladders and Tripods 146

4.56 Ropes and Buckets 146

4.57 Hard Hats 146

4.58 Protective Clothing 146

4.59 Other Equipment and Procedures 146

4.6 FINAL PRECAUTIONS BEFORE MANHOLE ENTRY 146

4.60 Health Conditions of Operators 146

4.61 Review of Required Tools, Materials and Equipment 148

4.62 Briefing 148

4.7 PROCEDURES DURING MANHOLE ENTRY 148

- 4.70 Confined Space Work Procedure 148
- 4.71 Operations of Manhole Entry 150
- 4.72 While Operator Is in the Manhole 151
- 4.73 Special Problems of Manhole Work 151
- 4.74 After Leaving Manhole 153
- 4.75 Responsibility 153

4.8 ELECTRICAL SAFETY 153

4.9 WORKING NEAR NOISE 160

4.10 FIRE FIGHTING 161

4.11 HAZARD COMMUNICATION (WORKER RIGHT-TO-KNOW LAWS) 161

4.12 ADDITIONAL READING 169

SUGGESTED ANSWERS 170

OBJECTIVE TEST 172

OBJECTIVES

Chapter 4 SAFE PROCEDURES

Following completion of Chapter 4 you should be able to:

1. Perform duties of a collection system operator by following safe procedures,
2. Inspect safety features of vehicles and equipment,
3. Drive vehicles defensively and safely,
4. Route traffic around a job site,
5. Identify manhole hazards,
6. Assemble necessary equipment to safely enter a manhole,
7. Calibrate and use gas detection equipment,
8. Take necessary precautions prior to entering a manhole,
9. Follow safe procedures during manhole entry, work and exit,
10. Avoid electrical hazards,
11. Protect yourself from excessive noise,
12. Extinguish fires, and
13. Interpret and comply with worker right-to-know laws.

GLOSSARY

Chapter 4 SAFE PROCEDURES

AEROBIC (AIR-O-bick) AEROBIC

A condition in which "free" or dissolved oxygen is present in the aquatic (water) environment.

AMBIENT AMBIENT

Surrounding. Ambient or surrounding atmosphere.

ANAEROBIC (AN-air-O-bick) ANAEROBIC

A condition in which "free" or dissolved oxygen is NOT present in the aquatic (water) environment.

CONFINED SPACE* CONFINED SPACE

Any space where *BOTH* of the following conditions exist at the same time.

A. Existing ventilation is insufficient to remove dangerous air contamination and/or oxygen deficiency which may exist or develop, and
B. Ready access or egress (getting out) for the removal of a suddenly disabled employee (operator) is difficult due to the location and/or size of the opening(s).

DANGEROUS AIR CONTAMINATION DANGEROUS AIR CONTAMINATION

An atmosphere presenting a threat of causing death, injury, acute illness, or disablement due to the presence of flammable and/ or explosive, toxic or otherwise injurious or incapacitating substances.

A. Dangerous air contamination due to the flammability of a gas or vapor is defined as an atmosphere containing the gas or vapor at a concentration greater than 20 percent of its lower explosive (lower flammable) limit.
B. Dangerous air contamination due to a combustible particulate is defined as a concentration greater than 20 percent of the minimum explosive concentration of the particulate.
C. Dangerous air contamination due to the toxicity of a substance is defined as the atmospheric concentration immediately hazardous to life or health.

OLFACTORY FATIGUE

OLFACTORY FATIGUE (ol-FAK-tory) OLFACTORY FATIGUE

A condition in which a person's nose, after exposure to certain odors, is no longer able to detect the odor.

OXYGEN DEFICIENCY OXYGEN DEFICIENCY

An atmosphere containing oxygen at a concentration of less than 19.5 percent by volume.

SEPTIC (SEP-tick) SEPTIC

This condition is produced by anaerobic bacteria. If severe, the wastewater turns black, gives off foul odors, contains little or no dissolved oxygen, and creates a high oxygen demand.

SEWER GAS SEWER GAS

(1) Gas in collection lines (sewers) that results from the decomposition of organic matter in the wastewater. When testing for gases found in sewers, test for lack of oxygen as well as the presence of explosive and toxic gases.
(2) Any gas present in the wastewater collection system, even though it is from such sources as gas mains, gasoline and cleaning fluid.

SPECIFIC GRAVITY SPECIFIC GRAVITY

(1) Weight of a particle or substance in relation to the weight of an equal volume of water. Water has a specific gravity of 1.000 at 4.0°C (or 39°F). Wastewater particles or substances usually have a specific gravity of 0.5 to 2.5.
(2) Weight of a particular gas in relation to the weight of an equal volume of air (or hydrogen) at the same temperature and pressure.

---

* *Confined Spaces, definition adapted from General Safety Orders, Article 108, Title 8, California Administrative Code, Cal/OSHA Consultation Service, Sacramento, California, October 1980.*

CHAPTER 4. SAFE PROCEDURES

4.0 PERFORM YOUR DUTIES SAFELY

Collection system operators have a very unique and challenging job because it includes a wide range of responsibilities and requires more than an average level of knowledge in many different areas. Clearly it requires a trained professional who is capable of exercising common sense under many different circumstances. In this job, more than in many others, an operator's knowledge, skills and common sense relate directly to SAFETY/SURVIVAL. A trained professional operator demonstrates an awareness of hazards and a commitment to accomplish every task in a safe manner. After receiving job assignments and discussing equipment needs, safety considerations and other aspects of the tasks, the first thing an operator generally does is get into a utility vehicle of some sort to get to the job site. This vehicle may range from a pickup truck to a very large cumbersome vehicle or a combination of vehicle and towed equipment. For example:

1. Tankers,
2. Rodding machines,
3. Boom trucks,
4. Standby power generators,
5. Foaming trailers,
6. TV/grout rigs,
7. Compressors,
8. Trailer mounted/engine driven pumps, and
9. Construction equipment.

Not only is the type of vehicle varied, but also the driving conditions which we frequently work in are varied. Most of our emergency situations occur when conditions are other than ideal so darkness, rain, cold, wind, fog, snow, ice or other weather conditions affect our ability to drive safely. Even when conditions are ideal, the equipment and traffic conditions frequently require extraordinary driving skills just to get to the job site.

Once at the site, the crew may be assigned one or more of the following tasks:

1. Working in a confined space such as a manhole, a metering vault, or a pump station wet well;
2. Working on or around electrical equipment found in pump station motor control centers;
3. Working on mechanical equipment such as pumps, bar screens, or compressors;
4. Working with hydraulic systems when installing a flow measurement weir or a bag plug to stop or control the flow;
5. Sampling industrial waste downstream from an industrial discharger;
6. Cleaning sewers;
7. Unplugging stopped up sewers;
8. Repairing broken or damaged sewers;
9. Working in a roadway where traffic control is required; and
10. Doing construction work involving trenching and shoring in or around other utilities (natural gas lines, phone and electrical utilities).

These are just a few examples that illustrate the range of equipment and jobs we must be familiar with.

OBJECTIVES

The objective of this chapter on *SAFE PROCEDURES* is to provide the collection system operator with insight into many of the actual hazards which exist in performing our everyday routine tasks. As always, awareness, knowledge, and a commitment to safety/survival, in addition to the technical skills required, will assist you in performing your assignments in a safe and professional manner. Specific sections in this chapter deal with the following topics:

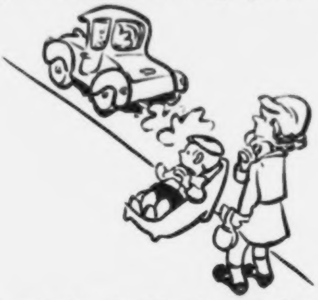
1. Vehicles,
2. Driving,
3. Traffic control,
4. Confined space,
5. Electrical safety,
6. Noise,
7. Fire, and
8. Worker "Right-To-Know."

In some cases, detailed procedures are included. Keep in mind, however, that these procedures may not cover all situation and, therefore, your own common sense is required. If state and local regulations and standards in your area require different procedures, you and you agency have a responsibility to develop and use other appropriate procedures. Carefully analyze each problem or regulation and develop appropriate procedures to meet those specific needs. Plan the way each job can be performed safely and you will not become an injury/fatality statistic to be included in the distressing statistics on the safety record of our profession as shown in Chapter 11.

REMEMBER
SAFE OPERATIONS ALWAYS TAKE PRECEDENCE
OVER EXPEDIENCY OR SHORT CUTS.

4.1 VEHICLE AND EQUIPMENT INSPECTION PROCEDURES

Most of the tasks that we do in our everyday life require preparation, regardless of how routine or mundane the task. For example, going to the grocery store requires that your car will start, that it will have enough gas, that you have the shopping list and the checkbook, and that you allocate a certain amount of time to accomplish the reasons for going to the store. Human nature being what it is, we typically will try to substitute a modified plan where we have used poor planning.



In our collection system business, the modifications and short cuts which result from not following established procedures can have serious consequences. Because of the hazardous nature of our jobs, poor planning increases the risk of injury and/or fatality to ourselves and co-workers. Therefore, one of the most critical aspects of your ability to perform your job in a professional manner occurs before you even leave the maintenance yard or shop. You and your agency should develop and follow established procedures for every collection system operation or activity.

1. Discuss the work assignments for the day with your colleagues, co-workers, supervisors.
2. Determine equipment needed; for example, atmospheric testing devices, traffic control devices, and material handling devices such as slings, hand tools not normally carried on your utility vehicles. Do you need any specialized equipment?
3. Inspect each piece of equipment you will be using to ensure it is working. It doesn't make sense to have atmospheric testing devices available if they are not calibrated, or they are inoperative. Your inclination will be to short cut procedures once in the field and jeopardize yourself and your co-workers' ability to survive. If there is any doubt about the functional capacity of an item, use replacement equipment while the defective or suspected equipment is repaired or further tested.
4. Inspect vehicles and towed equipment:
   a) Remember that most of our equipment is large/oversized/specialized equipment and therefore, procedures must be established to ensure safety and driveability once on the road. Driving equipment day in and day out may cause us to loose sight of the fact that this equipment has the following characteristics:
      1. Limited visibility,
      2. Reduced braking effectiveness,
      3. Top heavy (tankers),
      4. It may not be suitable for high speed highway driving,
      5. Reduced maneuverability, i.e., the ability to perform quick maneuvers to avoid an accident,
      6. May have special requirements to prevent or accommodate load shifting,
      7. Difficult to handle under unpredictable events such as a tire blowout, and
      8. Susceptible to reduced control under icy, wet, or high wind conditions.
   b) As part of the procedure before leaving the yard, the vehicle and any towed equipment should undergo a thorough mechanical/safety item inspection including:
      1. Mirrors and windows,
      2. Lighting system,
      3. Brakes,
      4. Tires,
      5. Trailer hitch/safety chain,
      6. Towed vehicle lighting system, and
      7. Auxiliary equipment such as winches/hoists.

Once your equipment and vehicle have been checked out, you and your crew are ready to depart the maintenance area. Ironically, many vehicle accidents occur before the crew is even out of the yard, due to the unusual nature of the equipment they are driving. Vehicles should be equipped with a backup alarm which sounds when the vehicle is placed in reverse to alert personnel in the area that the vehicle is backing up, usually under a limited visibility situation. Congestion in the yard, as well as the amount of activity with other vehicles and crews increases the hazard of an accident occurring at this period of time. An even better system, since most crews are two person crews, is to have one person behind the vehicle to guide and warn the driver.

NOTE: It is a good idea to weigh your loaded vehicle at least annually to ensure that you are not exceeding its gross vehicle rating (GVR). Depending on how vehicles are loaded and equipped, they will have varying pay load allowances. Weighing is easily accomplished for a very nominal fee at a large commercial truck scale. In the event that you are involved in an accident with an over-weight vehicle, you could be subject to criminal or civil charges.

4.2 DEFENSIVE DRIVING

Having made it safely out of the maintenance yard, the next hazard we face is getting to the job site safely, usually during rush hour and with heavy vehicle traffic conditions. Don't forget to *FASTEN YOUR SEAT BELTS*. Many states now have seat belt laws, and most agencies have seat belt policies. (See Volume II, Chapter 11, Section 11.9, "Safety/Survival Program Policies," for a typical Seat Belt Policy.)

Because collection systems are spread out, operators drive more miles annually on the job than the average person's total miles driven during a year. Therefore, defensive driving is an important factor in our daily routine.

Defensive driving is not only a mature attitude toward driving, but a strategy as well. You must always be on the alert for the large number of new drivers, inattentive or sleeping drivers, people driving under the influence of alcohol and/or drugs, and those drivers who are just plain incompetent. In addition, weather, construction, and the type of equipment you are driving can also present hazards. Some of the elements of defensive driving are:

1. Always be aware of what is going on ahead of you, behind you, and both sides of you;
2. Always have your vehicle under control;
3. Be willing to surrender your legal right-of-way if it might prevent an accident;
4. Know the limitations of the vehicle and towed equipment you are operating (stopping distance, impaired road vision, distance to change lanes safely, acceleration rate);
5. Take into consideration weather or other unusual conditions;
6. Develop a defensive driving attitude, that is, be aware of the situations that you are driving in and develop options to avoid accidents. For example, in residential areas you should assume that a child could run out into the street at any time, and always be thinking of what type of evasive action you could take. Be especially alert driving through construction areas during rush hour.
7. Rear end collisions, either due to driver inattentiveness or tailgating, are one of the most frequent types of vehicle accidents. Figure 4.1 illustrates the distance required for a vehicle to stop with ideal conditions and good brakes at various speeds, including the amount of time it takes for your brain to react. These figures are for passenger cars and, obviously, are increase significantly with most of the equipment that we operate on the road.

8. Keep in mind that you are driving a vehicle that is highly visible to the public. It may be necessary to swallow your pride when confronted by discourteous or unsafe drivers. Even when in the wrong, those types of drivers are quick to alert your agency, and thus your supervisor, to real or imagined violations which you committed while driving an agency vehicle.

Formal defensive driving programs are offered by many public and private agencies and are one of the special programs that should be incorporated into your Collection System Safety/Survival Program (see Chapter 11). These programs range from formal classroom training to actual defensive driving on a closed course using the vehicle you drive on your job every day. These courses are not only interesting and informative, but can can be fun as well. Suggested contacts in your area for defensive driving opportunities include:

1. State highway patrol,
2. Fire departments and local public safety (police) agencies,
3. Private trucking companies,
4. Private bus companies, and
5. Public transportation companies.

For a nominal fee, these organizations frequently will allow you and your co-workers to participate in their defensive driving programs.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 170.

4.0A List the different types of vehicles a collection system operator may be expected to drive.

4.1A Why must collection system operators follow established procedures?

4.1B What tasks should be performed BEFORE leaving the maintenance yard or shop?

4.1C What should an operator look for when checking out an atmospheric testing device before taking it out to a job site?

4.2A What is defensive driving?

4.3 ROUTING TRAFFIC AROUND THE JOB SITE

Assuming we have safely made it from the maintenance yard to the job site with our equipment, let's further assume

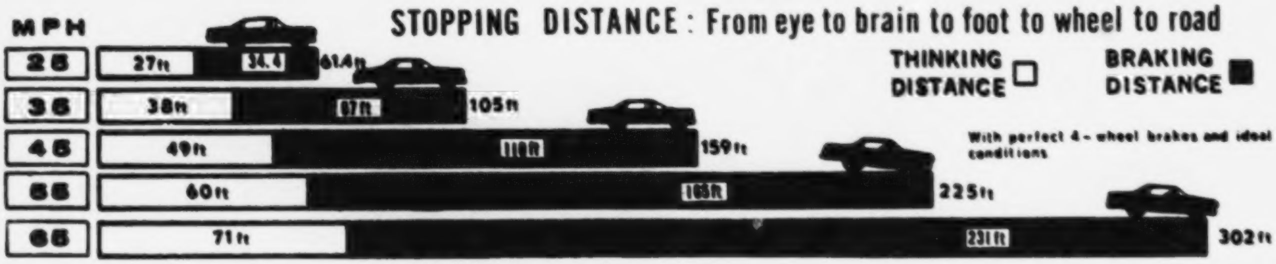


Fig. 4.1 Always maintain a safe stopping distance behind the vehicle in front of you.

(Courtesy of California Highway Patrol)

that we are going to be working in a manhole (a confined space) and that access to the manhole is the street. Both of these conditions require special procedures to be followed.

Upon arrival at the job site, look for a safe place to park vehicles. If they must be parked in the street to do the job, route traffic around the job site *BEFORE* parking vehicles in the street.

Working in a roadway represents a significant hazard to a collection system operator as well as pedestrians and drivers. Most states, counties, and cities have adopted regulations to control traffic and reduce the risk under different circumstances. This section illustrates examples of traffic control, which may or may not meet the specific requirements of the laws in your geographical area, but should serve to make you aware of various aspects of traffic control.

Any time traffic may be affected, appropriate authorities in your area must be notified before leaving for job site. These could be state, county, or local depending on whether it is a state, county, or local street. Frequently a permit must be issued by the authority which has jurisdiction before traffic can be diverted or disrupted. In some cases, traffic diversion or disruption may have an impact on the emergency response system in your area such as access by fire or police and so these agencies may be involved as well. In most cases, you will need to plan ahead to secure permits and notify authorities. This may mean only a phone call or two or it could mean several days' or weeks' advance planning if you need to make extensive traffic control arrangements.

Traffic must be warned of your presence in the street. "MEN WORKING" and "CAUTION, CONSTRUCTION WORK" signs are effective. Signs with flags or flashers and vehicles with rotating flashing lights are used to warn other motorists (Figures 4.2 and 4.3). Vehicle-mounted traffic guides are also helpful (Figure 4.4). Use flagmen to alert drivers and to direct traffic around the work site (Figure 4.5). Warning signs and flagmen must be located far enough in advance of the work area to allow motorists time to realize they must slow down, be alert for activity, and safely change lanes or follow a detour. Exact distances and the nature of the advance warning depend on traffic speed, congestion, roadway conditions and local regulations.

Once motorists have been warned, they must be safely routed around the job site. Traffic routing includes the use of flagmen and directional signs. Barricades and traffic cones properly placed can effectively channel traffic from one lane to another around the job site. Retain a traffic officer to direct traffic if streets are narrow and/or if there is considerable traffic or congestion.

If practical, park vehicles between on-coming traffic and the job site to serve as a warning barricade and to discourage reckless drivers from plowing into operators. Remember—you need protection from the drivers as well!

Answers to several questions will determine how traffic control should be accomplished.

1. Is traffic moving at a low speed (0-35 mph) or a high speed (40-55 mph)?
2. Is the street two-lane, one-way or two-way?
3. Is it undivided four-lane?
4. Is it multi-lane one-way?
5. Are pedestrian walkways affected?
6. Is it in a residential area?
7. Will a lane closure be required?
8. Will more than one lane be closed?
9. Will traffic control be required during peak traffic periods or at night?

Check your local and state laws and regulations for traffic control guidelines in specific circumstances and incorporate these control requirements into your agency's procedures.

In general, regardless of the location, the collection system operator must deal with five different areas of traffic control as shown in Figure 4.6. The five areas can be identified as:

1. Advanced warning area,
2. Transition area,
3. Buffer area,
4. Work area, and
5. Termination area.

1. ADVANCE WARNING AREA

The purpose of this area is to alert drivers to activity ahead and allow them enough time to alter their driving patterns prior to reaching the work area. Warnings can vary from a series of signs beginning a mile in advance of the work area to a single sign or flashing lights on a vehicle. An advance warning sign should be used when any problems or conflicts with the flow of traffic are anticipated. Guidelines for the placement of the advance warning area are:

1. One half-mile to one mile for freeways;
2. 1500 feet for most other roadways or open highway conditions; and
3. At least one block for urban streets.

2. TRANSITION AREA

When work is performed within one or more travel lanes, an enclosure is required. In the transition area, traffic is channeled from the normal traffic lane to the path required to move it around the work area. The transition area generally forms a taper by means of a series of pavement markings and or channeling devices placed on an angle to move traffic out of its normal path. See Figure 4.7 titled "Portable Arrows Eliminate Driver Confusion In Construction Area."

3. BUFFER SPACE

This open or unoccupied space between the transition and work areas provides an additional margin of safety for both traffic and working operators. If a driver fails to see the advanced warning, or fails to negotiate the transition, the buffer space provides room to stop before reaching the work area. This buffer area should be free of equipment, operators, materials, and operators' vehicles.

4. WORK AREA

Work area is that portion of the road which contains the work activity and equipment, is closed to the traffic and is set aside for exclusive use by operators, equipment, and construction materials. This area is obviously the most hazardous to the collection system operators since it is usually close to the traveled lanes (and therefore traffic), and it may be necessary to load or unload equipment within the work area.

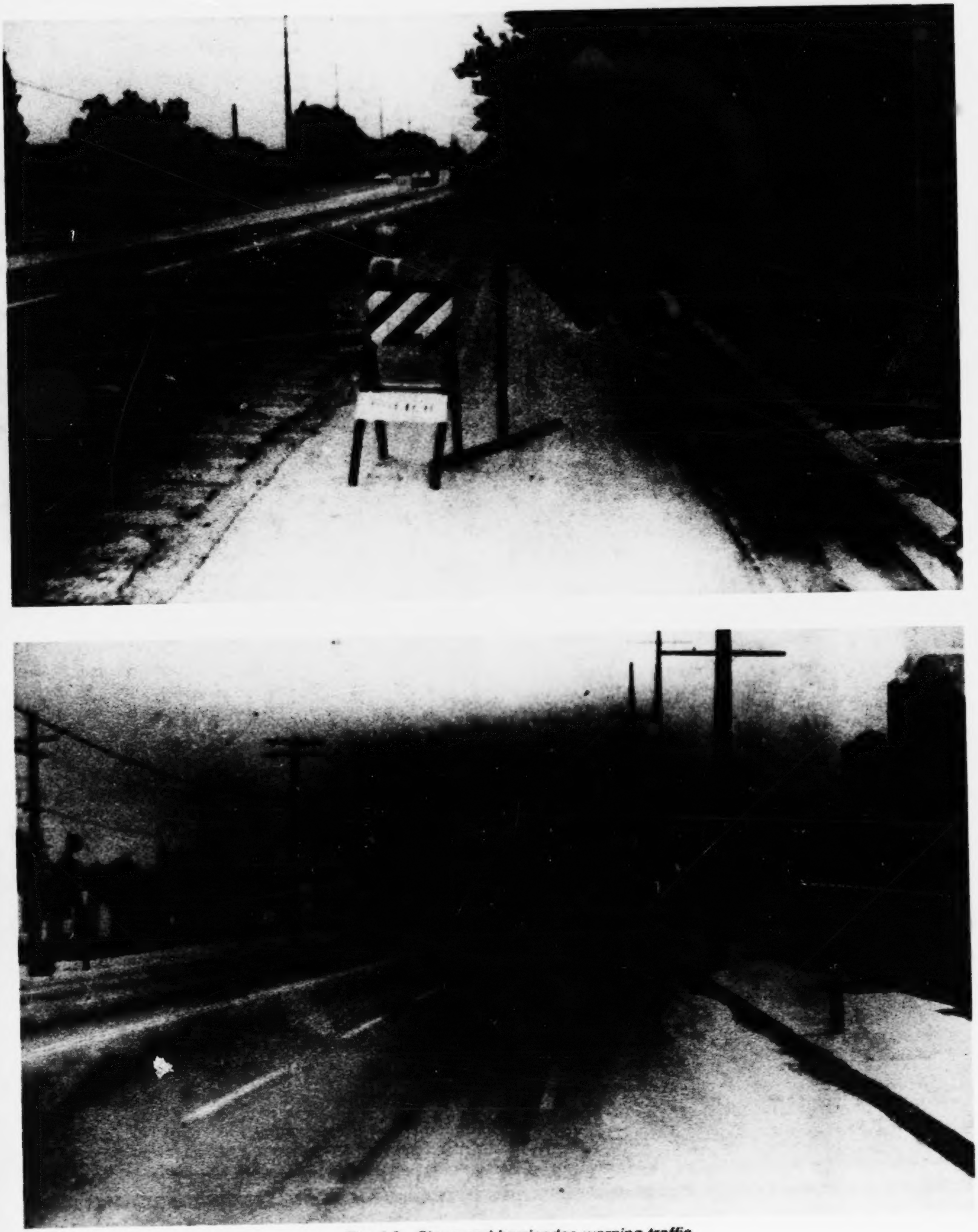


Fig. 4.2 Signs and barricades warning traffic

(Courtesy of the Bureau of Contract Administration, City of Los Angeles)

Fig. 4.3 Hi flags and cones routing traffic
(Courtesy of Water Quality Division, Sacramento County)

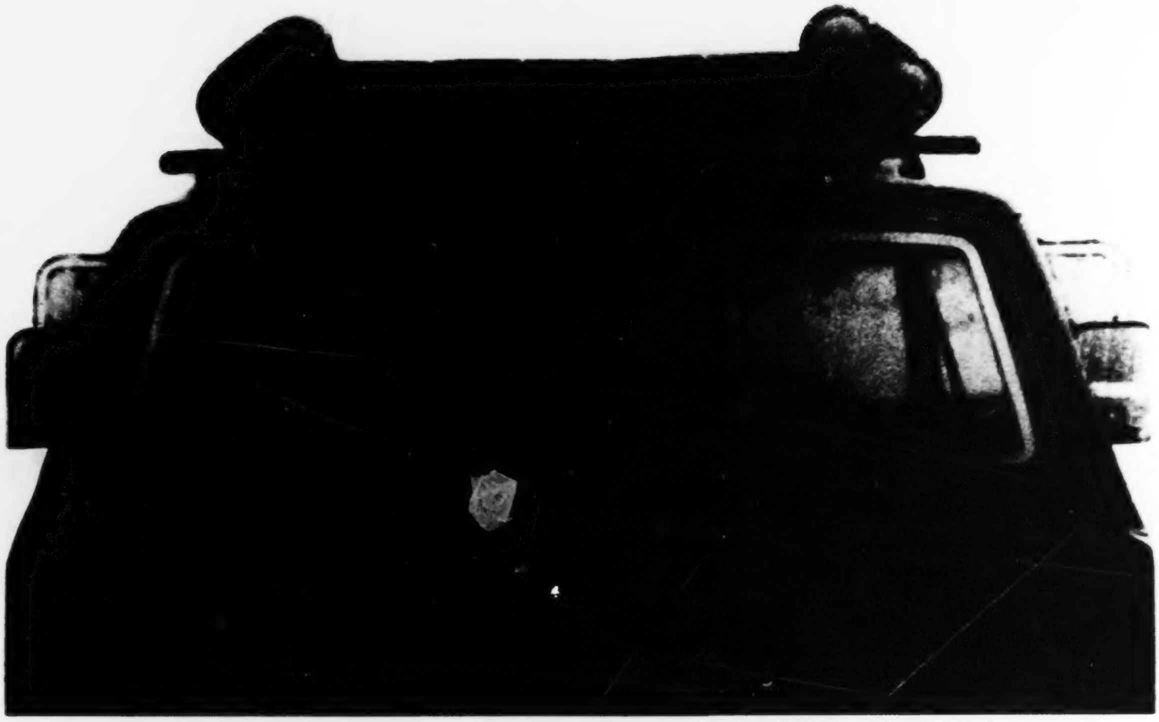


Fig. 4.4 Vehicle-mounted traffic guide
(Permission of Traffic Guide)

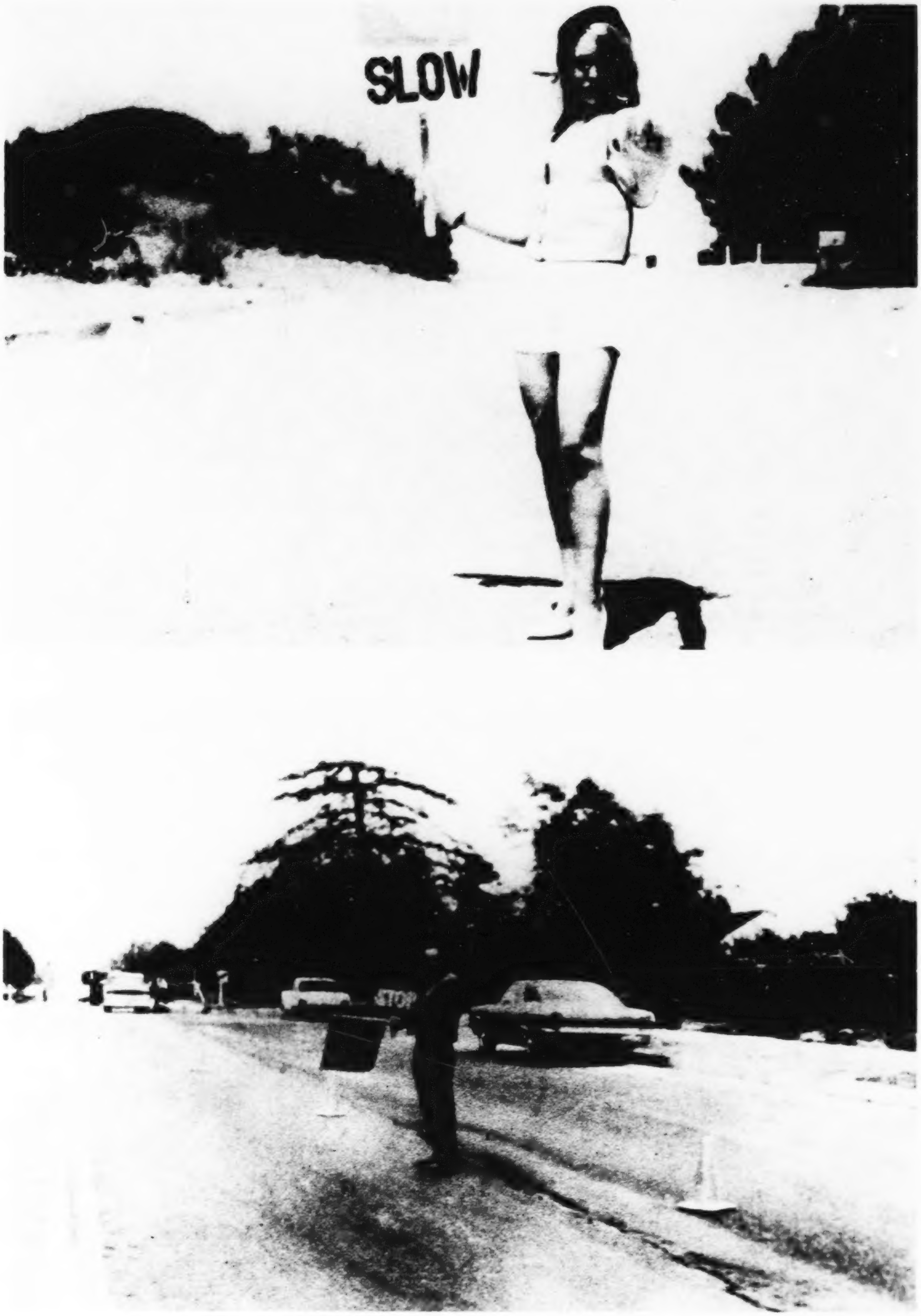


Fig. 4.5 Alerting and directing traffic
(Courtesy of the Bureau of Contract Administration, City of Los Angeles)

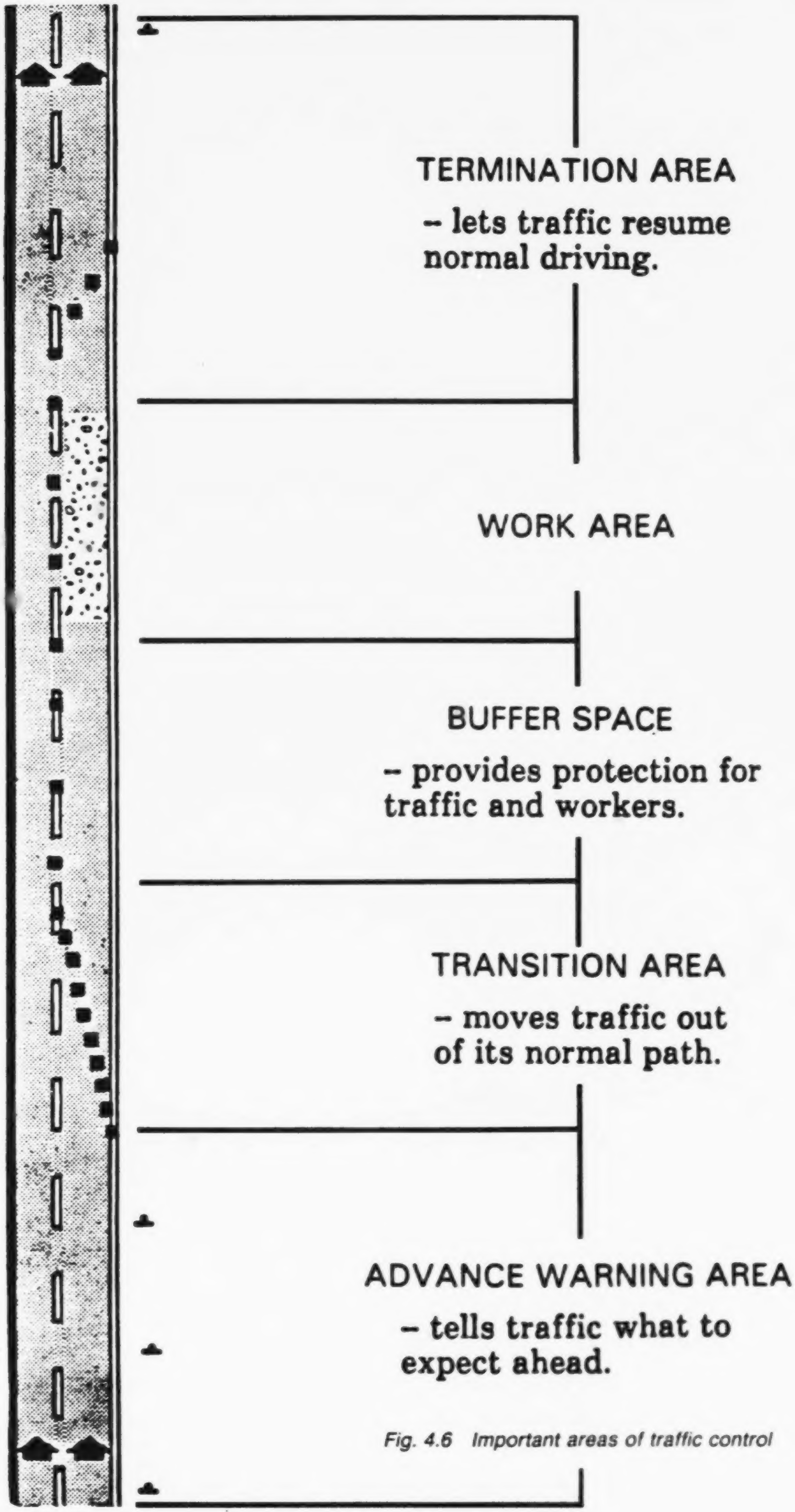
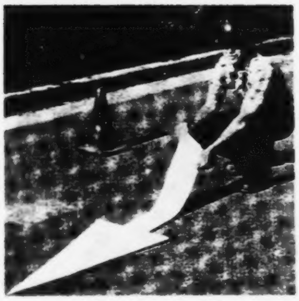

TERMINATION AREA
– lets traffic resume normal driving.
WORK AREA
BUFFER SPACE
– provides protection for traffic and workers.
TRANSITION AREA
– moves traffic out of its normal path.
ADVANCE WARNING AREA
– tells traffic what to expect ahead.

Fig. 4.6 Important areas of traffic control



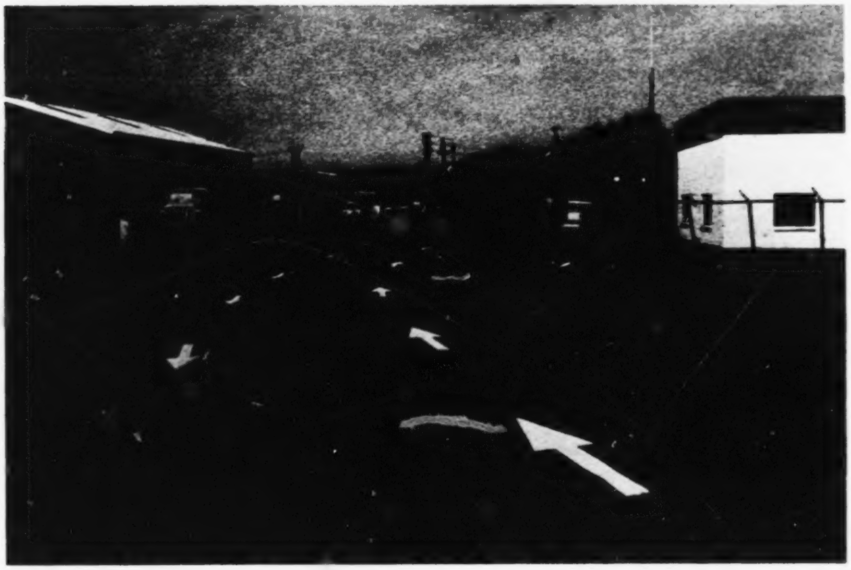


Fig. 4.7 Portable arrows eliminate driver confusion in construction area
(Permission of Safety Tech, Inc.)

5. TERMINATION AREA

This area provides a short distance for traffic to get clear of the work area and to return to the normal traffic lanes. A taper may be installed to channel the traffic back into the normal traffic lanes.

The next six pages show how to position hi flags, signs, and cones for flagman control and work under five typical conditions:

1. Work area in center of road,
2. Work beyond intersection,
3. Closing left lane,
4. Closing half-roadway, and
5. Closing right lane.

REMEMBER, YOU ARE SPEAKING A SIGN LANGUAGE... MAKE YOUR SIGNS SPEAK LOUD AND CLEAR!

ADDITIONAL READING

1. *MANUAL ON UNIFORM TRAFFIC CONTROL DEVICES FOR STREETS AND HIGHWAYS,* U.S. Department of Transportation, Federal Highway Administration, 1971. For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. Price $44.00. Stock Number 5001-0021.
2. *WORK AREA TRAFFIC CONTROL HANDBOOK,* Building News, Inc., PO Box 3031, Terminal Annex, Los Angeles, CA 90051. Price $3.00.
3. *WORK ZONE TRAFFIC CONTROL STANDARDS AND GUIDELINES,* 1985 Edition. For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. Price $2.75.
4. *TRAFFIC CONTROL DEVICES HANDBOOK,* 1983 Edition. For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. Price $20.00.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 170.

4.3A Who should be contacted before setting up a work site in a street?

4.3B How can traffic be warned of your presence in a street?

4.3C How can motorists be safely routed around a job site?

4.3D List the five different areas of traffic control.

4.4 CLASSIFICATION AND DESCRIPTION OF MANHOLE HAZARDS

Let's review what we have accomplished so far:

1. Received our work assignments;
2. Reviewed and discussed work assignments with colleagues and supervisors;
3. Inventoried tools and equipment to ensure that we have the appropriate tools to accomplish the work assignment;
4. Inspected all tools and equipment to ensure they are in good, safe working order;
5. Inspected and checked all safety equipment and calibrated testing devices (including zero check) as required;
6. Inspected vehicles or other rolling stock which we will be using;
7. Driven safely to the first job site; and
8. Set up adequate traffic controls.

We are now ready to proceed with our first work assignment for the day. We are going to inspect a manhole in an interceptor which is upstream from one of our lift stations, and which is suspected of surcharging due to accumulated grease, causing a partial stoppage of the line. This brings us to another area of routine assignments which can be particularly hazardous, and requires extreme care and professionalism in order to accomplish the task safely and survive potential hazards. Let's look in more detail at what kinds of manhole hazards we might encounter.

There are six major categories of hazards a person may encounter when entering a manhole. These hazards are discussed in order of known frequency of accidents and deaths to operators—atmospheric, physical injury (slips, falls, falling objects, sharp objects, bumps and structural failures), infection and disease, insects and biting critters, toxic exposure, and drowning.

4.40 Confined Spaces

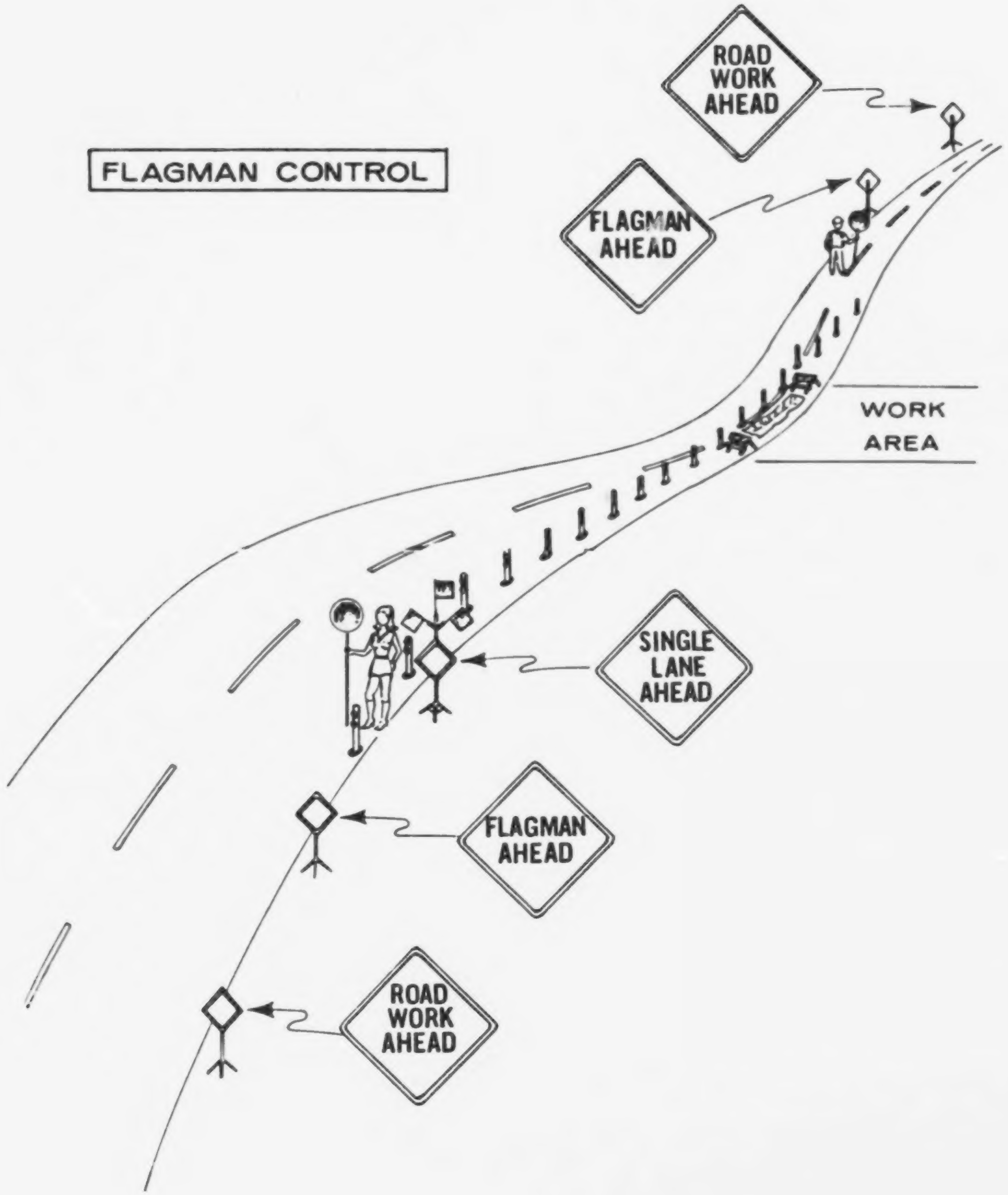
Manholes are considered *CONFINED SPACES.*[1] Therefore, entry into a manhole is considered entry into a confined space. Special safety rules and regulations have been developed to protect the life and health of persons who must enter confined spaces. Throughout this manual safe procedures for the entry of manholes and confined spaces will be emphasized.

DEFINITIONS

1. CONFINED SPACE. Any space where *BOTH* of the following conditions exist at the same time:

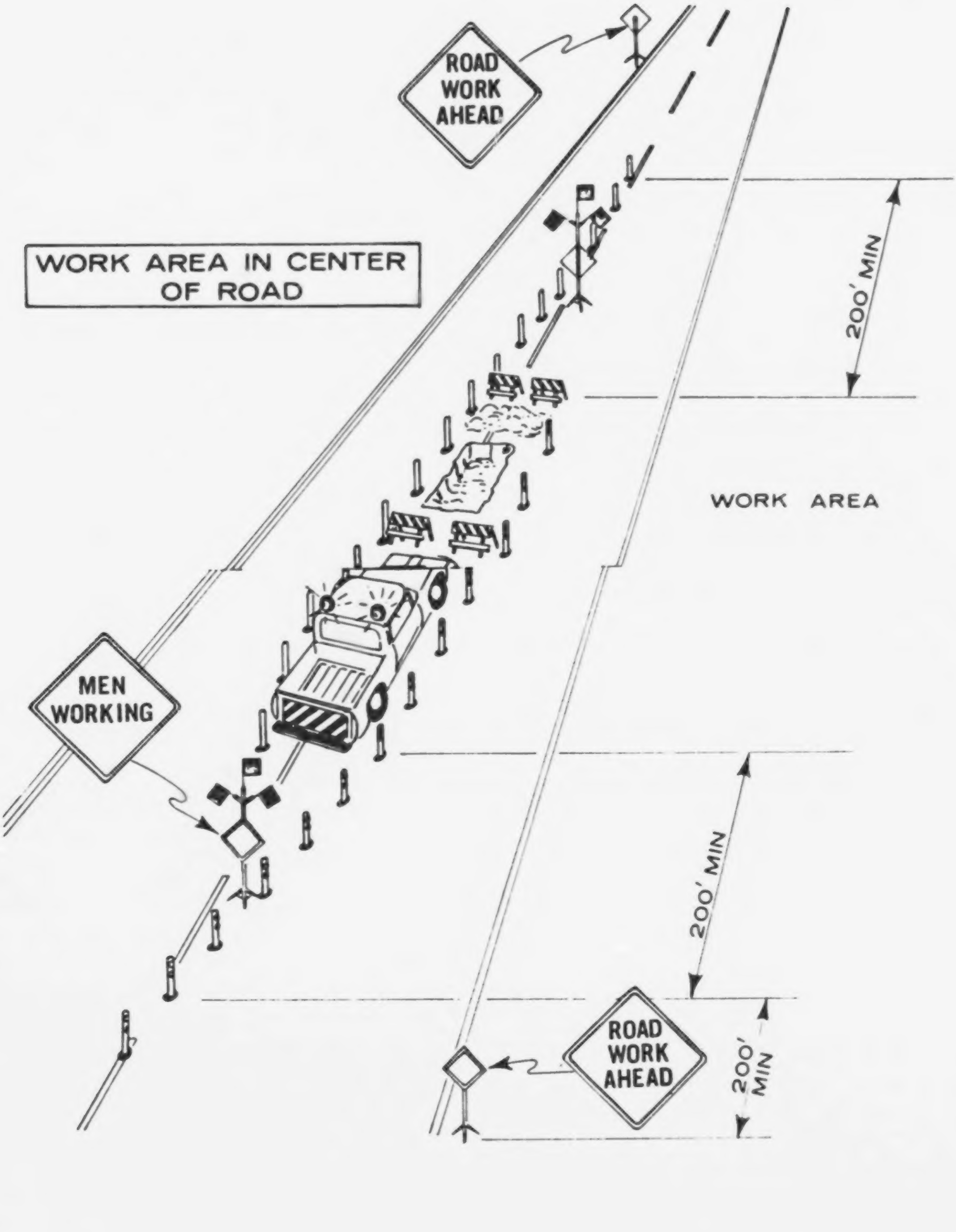
---

[1] *Confined Spaces, definition adopted from General Industry Safety Orders, Article 108, Title 8, California Administrative Code, Cal/OSHA Consultation Service. Sacramento, California, October 1980. NOTE: Your state or province may have a DIFFERENT legal definition of a confined space.*


FLAGMAN CONTROL
ROAD WORK AHEAD
FLAGMAN AHEAD
WORK AREA
SINGLE LANE AHEAD
FLAGMAN AHEAD
ROAD WORK AHEAD

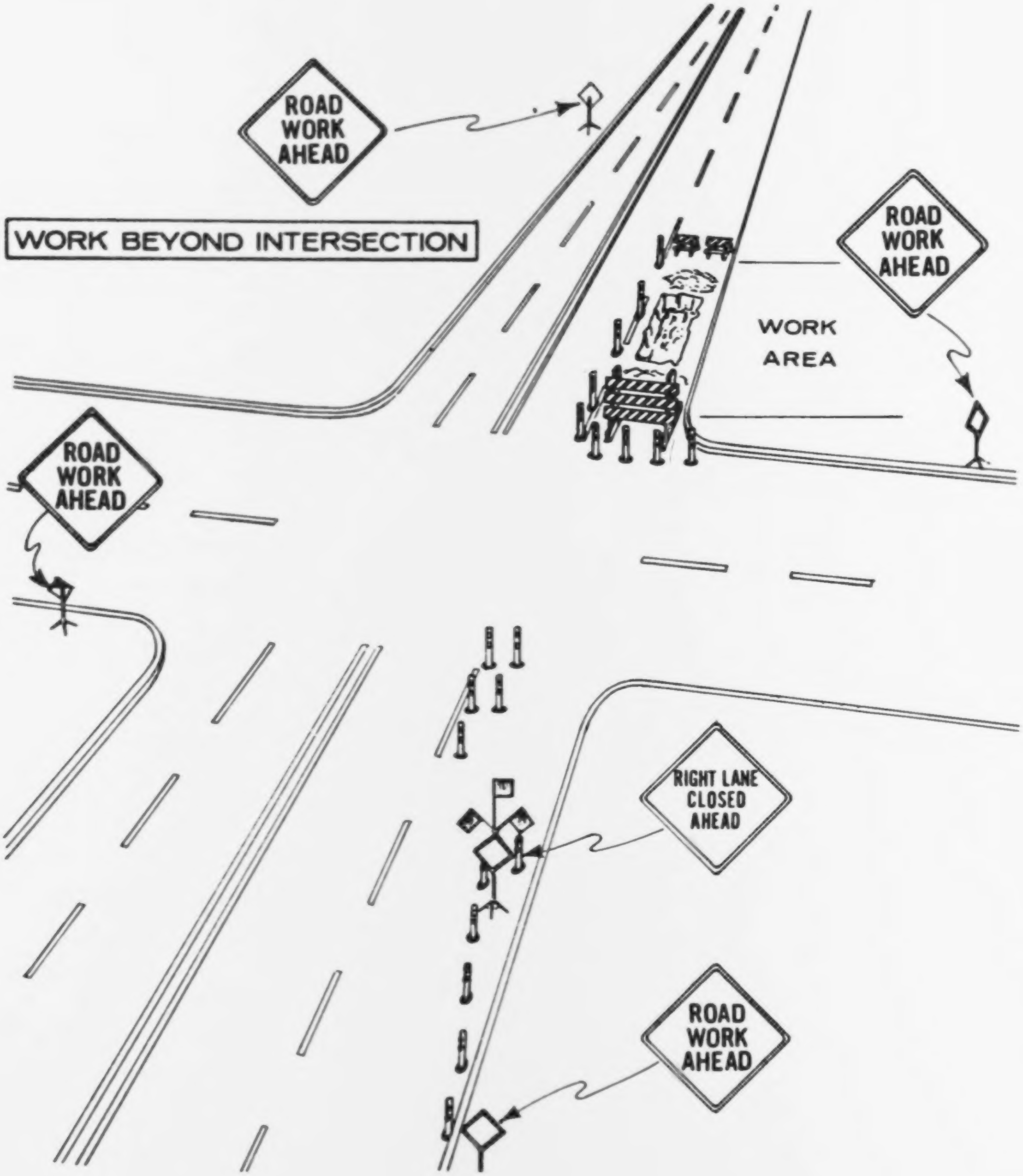
FLAGMAN CONTROL

(Courtesy San Diego Chapter, American Public Works Association)


ROAD WORK AHEAD
WORK AREA IN CENTER OF ROAD
200' MIN
WORK AREA
MEN WORKING
200' MIN
ROAD WORK AHEAD
200' MIN

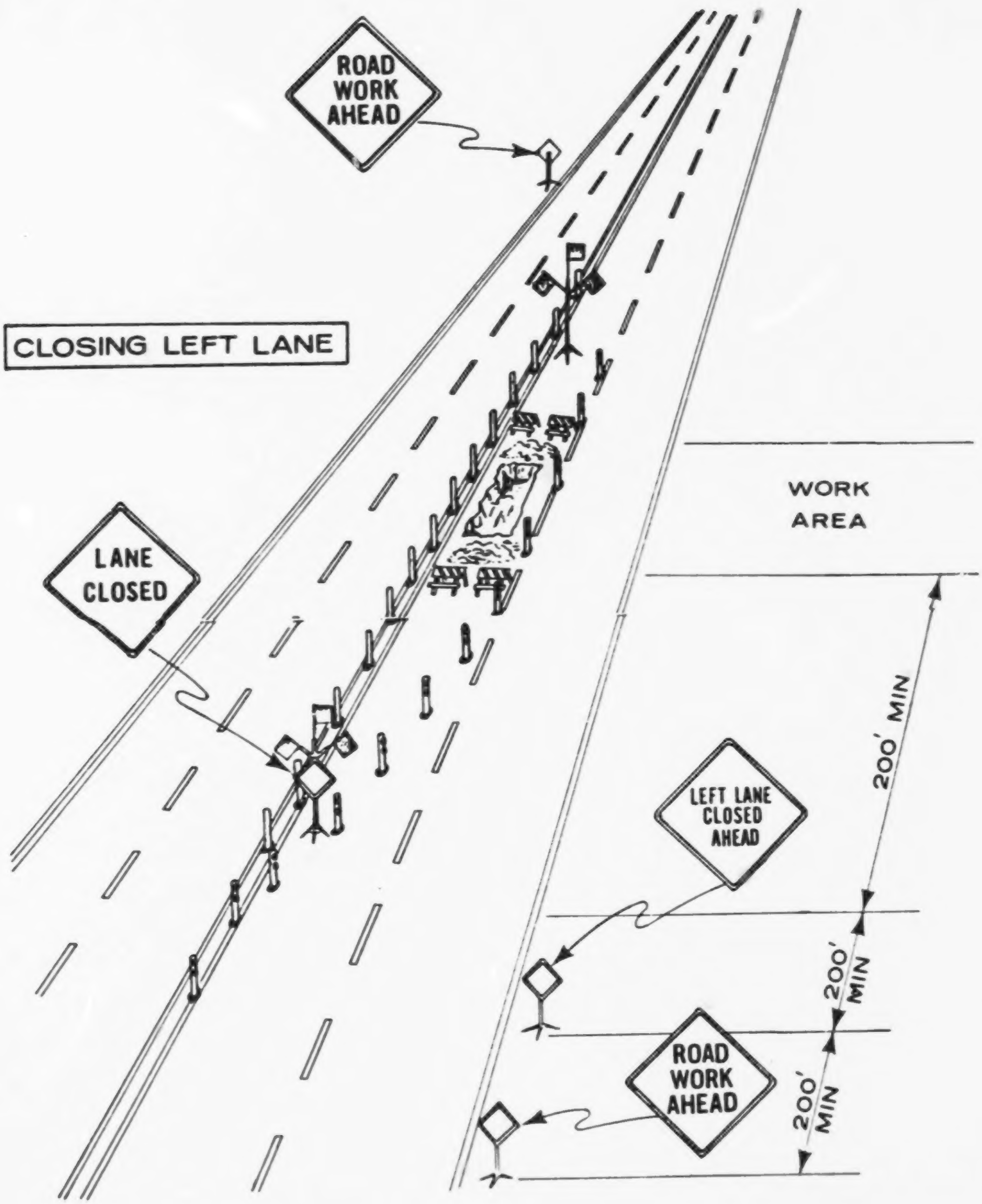
WORK AREA IN CENTER OF ROAD

(Courtesy San Diego Chapter, American Public Works Association)


ROAD WORK AHEAD
WORK BEYOND INTERSECTION
ROAD WORK AHEAD
WORK AREA
ROAD WORK AHEAD
RIGHT LANE CLOSED AHEAD
ROAD WORK AHEAD

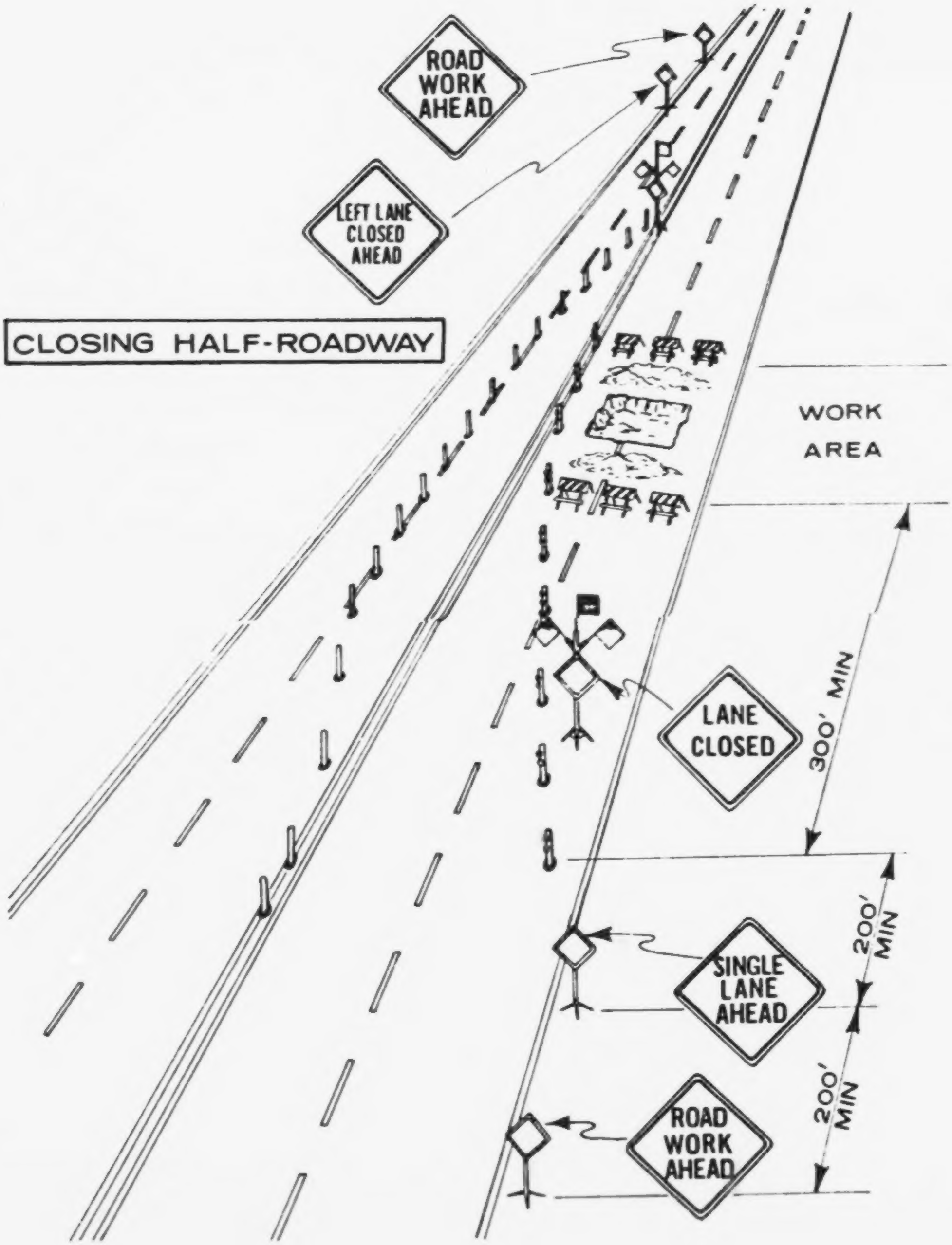
WORK BEYOND INTERSECTION

(Courtesy San Diego Chapter, American Public Works Association)


ROAD WORK AHEAD
CLOSING LEFT LANE
WORK AREA
LANE CLOSED
200' MIN
LEFT LANE CLOSED AHEAD
200' MIN
ROAD WORK AHEAD
200' MIN

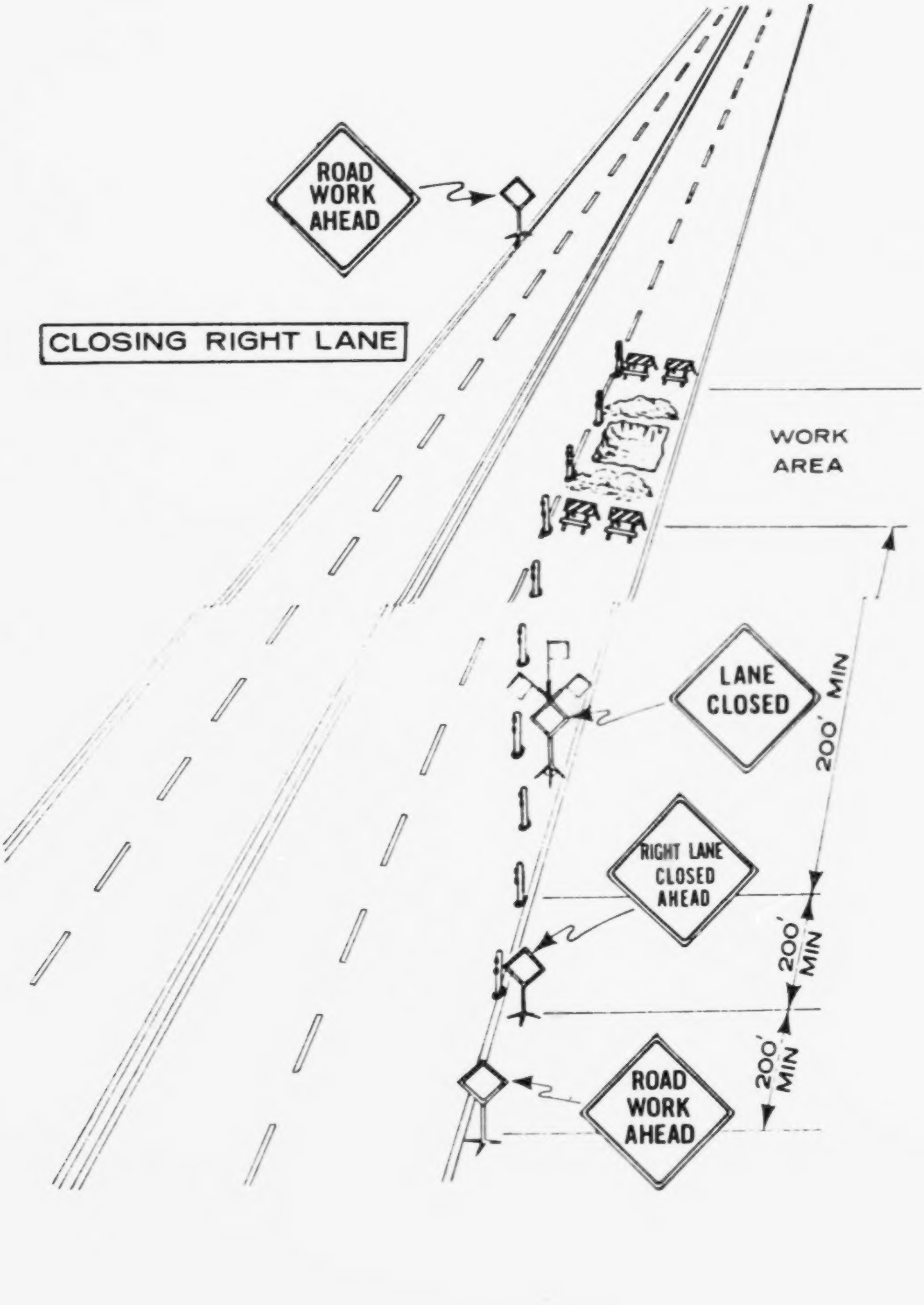
CLOSING LEFT LANE

(Courtesy San Diego Chapter, American Public Works Association)


ROAD WORK AHEAD
LEFT LANE CLOSED AHEAD
CLOSING HALF-ROADWAY
WORK AREA
LANE CLOSED
300' MIN
SINGLE LANE AHEAD
200' MIN
200' MIN
ROAD WORK AHEAD

CLOSING HALF-ROADWAY
(Courtesy San Diego Chapter, American Public Works Association)

142


ROAD WORK AHEAD
CLOSING RIGHT LANE
WORK AREA
LANE CLOSED
200' MIN
RIGHT LANE CLOSED AHEAD
200' MIN
200' MIN
ROAD WORK AHEAD

CLOSING RIGHT LANE

(Courtesy San Diego Chapter, American Public Works Association)

a. Existing ventilation is insufficient to remove dangerous air contamination and/or oxygen deficiency which may exist or develop, and

b. Ready access or egress (getting out) for the removal of a suddenly disabled employee (operator) is difficult due to the location and/or size of the opening(s).

The definition of confined space includes the terms "dangerous air contamination" and "oxygen deficiency." These terms are defined under headings 2 and 3 below.

2. DANGEROUS AIR CONTAMINATION. An atmosphere presenting a threat of causing death, injury, acute illness, or disablement due to the presence of flammable and/or explosive, toxic, or otherwise injurious or incapacitating substances.

   a. Dangerous air contamination due to the flammability of a gas or vapor is defined as an atmosphere containing the gas or vapor at a concentration greater than 20 percent of its lower explosive (lower flammable) limit. (See Figure 4.8.)

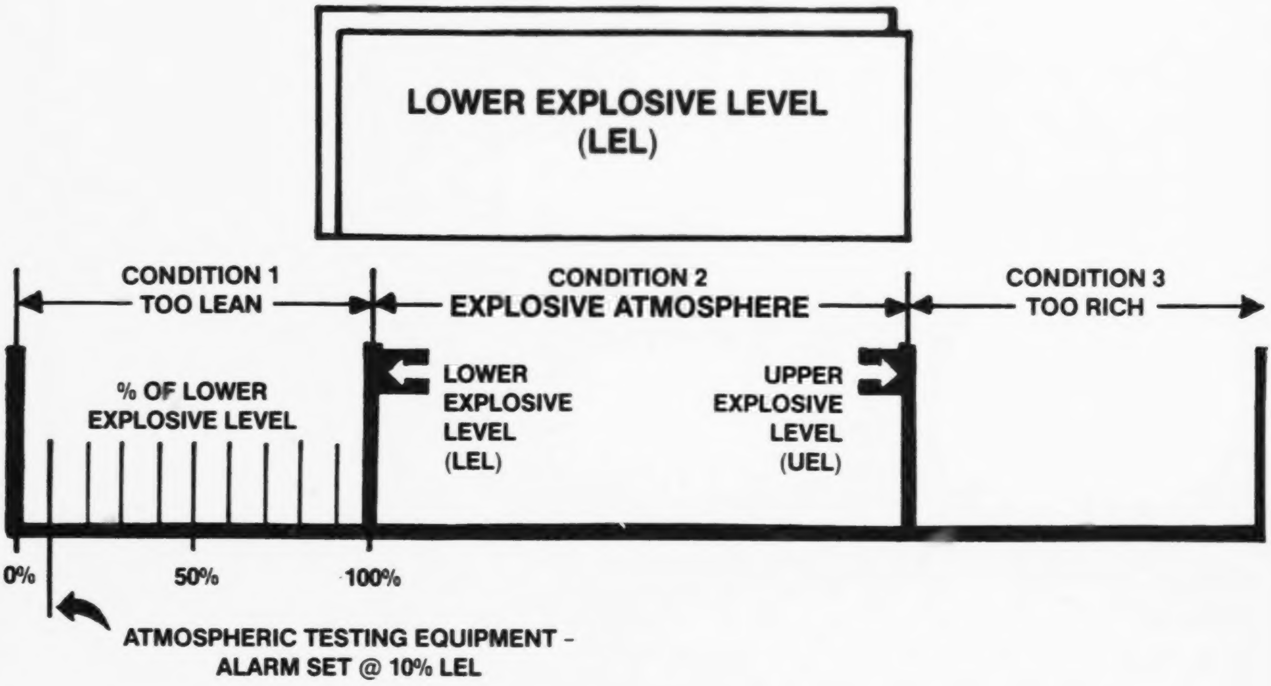
   b. Dangerous air contamination due to a combustible particulate is defined as a concentration greater than 20 percent of the particulate's lower explosive (lower flammable) limit.

   c. Dangerous air contamination due to the toxicity of a substance is defined as the atmospheric concentration immediately hazardous to life or health.

3. OXYGEN DEFICIENCY. An atmosphere containing oxygen at a concentration of less than 19.5 percent by volume.

WARNING: Your state or province may have DIFFERENT rules and regulations regarding the procedures for entry and work in confined spaces than outlined in this training manual. YOU must determine the rules, regulations and procedures applicable to your situation and comply with them.

In some states all manholes are considered confined spaces until the atmosphere has been tested for toxic gases, lower explosive limit and oxygen level. If everything tests OK, the manhole can be declared a safe work area. The manhole is ventilated and the atmosphere is monitored continuously. Access to the manhole is provided by wooden or aluminum ladders. Under these circumstances procedures different from confined space entry procedures may be safe and approved.



THREE ATMOSPHERIC CONDITIONS CAN EXIST

1. TOO LEAN TO SUPPORT COMBUSTION
2. MIXTURE JUST RIGHT, EXPLOSION OCCURS
3. MIXTURE TOO RICH TO SUPPORT COMBUSTION

Fig. 4.8 Lower explosive limit (LEL)

4.41 Atmospheric Hazards

Atmospheric hazárds consist of three major types—explosive or flammable, toxic atmospheres, and depletion or elimination of breathable oxygen. Do not allow unhealthy odors to distract your attention from the three major types of hazards that could kill you.

1. Explosive or flammable atmospheres can develop at any time in the collection system. Flammable gases or vapors may enter a sewer or manhole from a variety of legal, illegal or accidental sources. These conditions can be measured by the use of meters (LEL) that indicate the explosive or flammable limits of the atmospheres. The atmospheres in manholes must be tested prior to entering a manhole and while the manhole is occupied.

   a. Methane gas is one of the products of waste decomposition. This gas can be produced almost anywhere in a collection system. Methane is also the major flammable gas in the natural gas piped under streets by utility companies. Leaks in these pipes will saturate the soil around a sewer pipe, and seepage will result in the gas entering the collection system and endangering operators in a manhole.

   Methane gas in its normal state is colorless, tasteless, and odorless, and therefore, we cannot detect it through our normal senses. Natural gas which is supplied through the piping network of a natural gas utility has an odorant added to it so that we are able to detect by smell the presence of natural gas leaks; for example, in our home heating system. When a leak occurs underground and the gas travels through the ground, the ground acts as an odor filter and removes the odor which was added. As a result, the underground natural gas leak is most likely going to be undetectable by smell because of the absence of the odorant.

   b. Because methane and natural gases are lighter than air, a small portion of the gas will diffuse or escape from a manhole if there is natural ventilation. On the other hand, propane, gasoline, solvents and other explosive fuel gases may be as much as two-and-one-half times heavier than air. They will tend to accumulate (if there is not ventilation) in the pockets of the lower portions of a collection system to form explosive mixtures or to displace air.

Underground sources of explosive or flammable gases include gasoline storage tanks, gas stations, and petroleum product pipelines which may be leaking. Accidental spills caused by traffic accidents involving tank trucks hauling flammable materials are very common, and more often than not, will find their way into the inlet basins connected to storm drains or combined sewers. Similarly, discharging of flammable materials, either accidentally or illegally, from industrial sources is a common source of flammables which end up in the collection system. Many of these compounds also have the ability to displace available oxygen, so even if they do not cause a fire or explosion, they may cause death or injury by asphyxiation. If they are heavier than air (*SPECIFIC GRAVITY*[2] of greater than 1, which is equal to air), the gas will accumulate at the bottom of the manhole or underground structure and displace the oxygen in the lower section. Therefore, you can't assume that even if the top portion tests okay, that the bottom section of the structure will have a safe atmosphere.

2. Toxic atmospheres (poisonous air) in wastewater collection systems or storm collection systems are most likely to result from the presence of hydrogen sulfide (H_2S), a gas produced by the decomposition of certain materials containing sulfur compounds. Hydrogen sulfide gas quickly mixes with air and goes wherever the air goes. If there is no ventilation or air movement, hydrogen sulfide accumulates in the lower sections of the collection system, since it has a specific gravity of 1.19 and is therefore heavier than air. Hydrogen sulfide can be detected by the smell of rotten eggs, although this is not a reliable method of testing. Hydrogen sulfide gas also has the unique ability to affect your sense of smell. After a short exposure to hydrogen sulfide gas, you will experience a loss of the ability to detect hydrogen sulfide gas by smell; therefore, instrumentation must be used to detect the gas.

   As with the flammable or explosive materials, toxics may also enter the collection system from accidental sources such as spills in industrial plants, or mobile tank transporters such as rail cars and tank trucks which are involved in accidents. Other toxic gases that may be encountered include carbon monoxide, chlorinated solvents and industrial toxins (poisons), depending on wastes discharged to the collection system. As a professional collection system operator, you should be aware of the potential sources of these materials from industrial/commercial operations in your specific area.

3. The amount of breathable oxygen present in a manhole or other underground structure can be dangerously decreased or even eliminated when the air is mixed with or replaced by another gas. Meters are available that measure the concentration of oxygen in the air. Do not work in confined spaces where the atmosphere contains less than 19.5 percent oxygen. ALWAYS VENTILATE THE MANHOLE before entry and continuously during occupancy. CONTINUOUSLY TEST all levels of manhole for oxygen deficiencies and explosive and toxic conditions.

   Concentrations of oxygen in a structure may exceed the level in the air we normally breathe (21.9 percent) when pure oxygen (0_2) is used to prevent *SEPTIC*[3] conditions and the production of hydrogen sulfide in the wastewater collection system (see Chapter 6, Section 6.6, "Hydrogen Sulfide Control"). If the manhole is continuously ventilated and the oxygen level continuously measured, no problems should develop. A higher-than-normal level of oxygen won't hurt you, but will increase the fire or explosive hazard.

---

[2] *Specific gravity. (1) Weight of a particle or substance in relation to the weight of an equal volume of water. Water has a specific gravity of 1.000 at 4.0°C (or 39°F). Wastewater particles or substances usually have a specific gravity of 0.5 to 2.5. (2) Weight of a particular gas in relation to the weight of an equal volume of air (or hydrogen) at the same temperature and pressure.*

[3] *Septic (SEP-tick). This condition is produced by anaerobic bacteria. If severe, the wastewater turns black, gives off foul odors, contains little or no dissolved oxygen, and creates a high oxygen demand.*

4.42 Physical Injury

Physical injury during manhole entry can occur from several causes. Operators in restricted spaces with uneven footing often have poor balance and decreased coordination. The handling of tools in restricted spaces often means an operator is working in awkward positions which can cause strained muscles or tendons, bruises, or torn skin if the operator is not careful.

The use of heavy ladders for manhole entry and exit has been prohibited in many communities after these ladders were dropped by accident while an operator was in a manhole. Portable, light weight, aluminum alloy ladders and rope ladders have proven to be satisfactory substitutes. Similarly, the practice of installing metal rungs in manhole walls also has been discontinued by some agencies because the rungs or the concrete holding them was being eaten away and destroyed by the highly corrosive atmospheres of the collection system. Manhole rungs should always be suspected as being unsafe. *NEVER* use them without some type of fall protection device.

Dropping tools to operators in a manhole and tossing the tools back out causes many physical injuries. In order for you to see to catch a tool being dropped, you must look upward and into the brighter light, causing temporary loss of visual capacity. In addition to this problem, dust and debris from the street or manhole ring can fall into your eyes, again causing vision problems as well as possible eye infection if you attempt to wipe your eyes with a hand or glove that has been exposed to the wastewater environment.

Tools should be lowered into and pulled out of manholes in a bucket or sling, preferably before the operator enters the manhole. In the event that it is necessary to lower or raise tools and equipment while in the manhole, they must be secured in such a manner so that if the bucket tips (for example), or the bottom of the bucket gets hung up on a manhole rung and tips, the tools cannot fall out of the pouch or bucket and hit the operator working in the manhole. Many collection system and treatment plant agencies use a truck winch or a tripod and winch (Figure 4.9) to lower an operator and tools into a manhole.

The use of glasses or safety goggles in a manhole may be difficult because of their tendency to fog. These glasses also can become smeared by moisture in a manhole environment and thus reduce the operator's vision. Proper ventilation will reduce fogging problems. If a chipping gun or other tool is being used to chip concrete or pipe, safety glasses or goggles MUST be worn. In some cases, a full face safety shield may work better than safety glasses or goggles. Hard hats must also be worn when working in manholes.

When working in a manhole, beware of sharp objects tht can cut or penetrate your skin and cause a serious infection. Typical sharp objects include razor blades, pins, hypodermic needles and broken pieces of glass and metal.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 170.

4.4A List the major categories of hazards you may encounter when entering a manhole.

4.4B What is a confined space?

4.4C Why can the top portion of the atmosphere in a manhole test "safe" when the bottom portion could be dangerous?

4.4D What kinds of atmospheric hazards are encountered in manholes?

4.4E What are some of the causes of physical injuries in manholes?

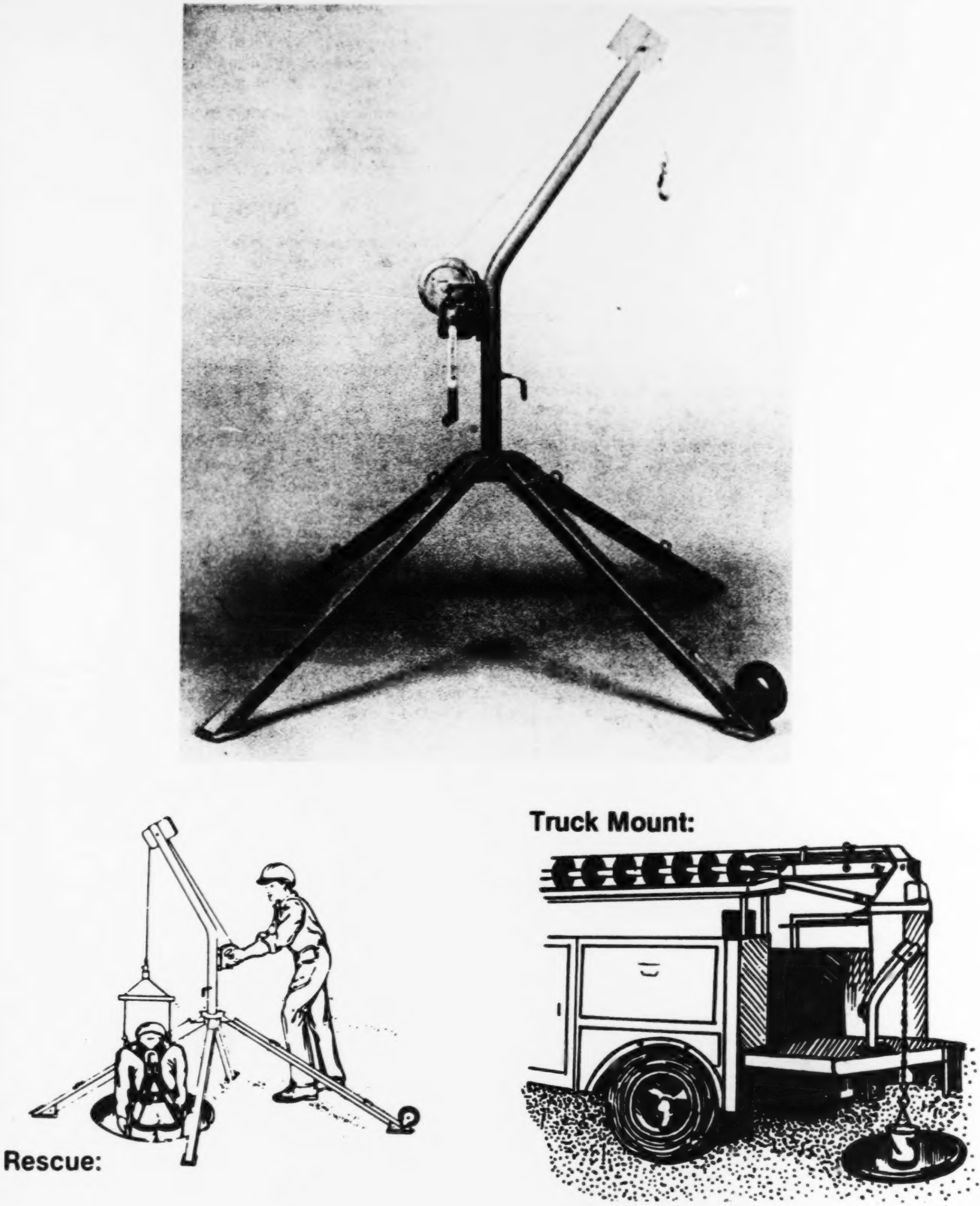
4.43 Infections and Diseases

Infections are always potentially present when you enter a manhole. Every disease, parasite, infection, virus and illness of a community can end up in the wastewater collection system. Persons required to enter manholes are thus automatically exposed to these infections and diseases. Leptospirosis can be transmitted to operators through the urine and feces of rats living in sewers. This disease causes fever, headaches, nausea, muscular pains, vomiting, and thirst. Contact your safety officer or doctor regarding inoculations for typhoid, paratyphoid, polio and tetanus. As previously mentioned, the practice of dropping tools into a manhole can cause contaminated particles to fall into an operator's eyes. Other sources of infection include rubbing one's face or eyes with contaminated hands or clothing; cuts from sharp objects in a contaminated environment; and eating or smoking on the job without first thoroughly washing your hands. Personal cleanliness is your best means of protection against infection.

Boots, heavy gloves, and rain suits are examples of protective clothing suitable for working in manholes. Uniforms, coveralls, and other clothing which become soiled should be cleaned by a commercial laundry service rather than being washed with the family laundry. Keep your work clothes separated from your street clothes by using two lockers, one for uniforms and one for street clothes.

If you must work in a manhole that is located reasonably close to the discharge of a hospital, venereal disease treatment center, clinical laboratory, surgical facility, or a veterinarian's office and hospital, it may be advisable to disinfect the manhole and the upstream line one or two hours ahead of scheduled entry. This action could result in other problems and strong odors in the manhole, but will significantly reduce the risk of exposure to the diseases which are possible in such manholes. Because disinfectants are poisons, do not enter a manhole when the odor of a disinfectant is present.

Most state and local health departments have laws and regulations that prevent the discharge of infectious wastes



Rescue:

Truck Mount:

Fig. 4.9 Tripod and winch for lowering and removing operators and tools from manholes

(Permission of Services & Materials Co., Inc.)

into wastewater collection systems until after they have been disinfected (usually in an autoclave that disinfects by using steam). Contact the medical officer in charge of any medical facility immediately upstream from manholes and sewers in which you must work. This person can explain the disinfection procedures used by the medical facility, indicate if the threat to your health is greater than usual, and recommend any special precautions or disinfectants that may be necessary.

4.44 Insects, Bugs and Rodents

Insect, bug and rodent bites, though somewhat uncommon, are a double hazard to operators. The insects themselves may be poisonous to humans, such as the black widow spider and the violin spider. Many other types of insect, bug and rodent bites can lead to infection or serious illness. Rat bites, for example, can transmit rabies and mosquito bites sometimes transmit malaria.

Wear protective clothing and be alert to the possible danger to your health. If you are bitten, gently wash the area with soapy water. Get prompt medical attention if you develop any signs of redness or swelling, or if you develop a fever or an allergic reaction. Following is a list of insects and bugs which have been found in manholes.

Stinging insects such as wasps, mud daubers and bees
Ticks
Fleas
Lice
Mosquitos
Houseflies
Blowflies
Cockroaches

Always inspect a manhole for insects, bugs and rodents before entering.

Where insects have been a problem, and where rats or other vermin may occupy a collection system or where epidemics of insect-borne diseases may be present, spraying a manhole with an insecticide is suggested. The solution should be water-soluble and leave a toxic residue to be effective against the next hatch of any insects present and breeding in the collection system. Spraying should be conducted at time of entry if insects or other problems are observed. Ventilate manhole so insecticide will not be inhaled by operators. If a manhole is especially filthy or odorous from an insecticide or hydrogen sulfide, wash down the manhole with a high-velocity stream of water. This wash is best accomplished within an hour or so before manhole entry.

4.45 Toxicants

Toxicants include any substances that act as poisons. Acids, bases and other hazardous liquids or solid chemicals are sometimes discharged into the wastewater collection system by either accidental spills or deliberate action by industry or the public. Exposure to such toxic substances is always a potential health hazard for the collection system operator. Proper boots and gloves are effective means of protection against these toxicants.

Contact your pretreatment inspector or industrial waste section when working in industrial/commercial areas for possible toxicants that may be encountered when working in the collection system in the area. If you discover a strong or unusual odor or color in the wastewater, request your supervisor to notify the pretreatment inspection or industrial waste section of your agency.

4.46 Drowning

With the trend towards larger regional wastewater treatment plants, intercepting sewers are being constructed to convey large flows. These large-diameter sewers and high flows increase the chances of an operator drowning from an accidental slip or fall into the flowing wastewater. To avoid drowning, watch your step at all times, especially when working near or in large flows. Wear life jackets and use lifelines if the flow in the sewer is capable of washing a fallen or unconscious operator away and if the operator will fit into the downstream pipe.

4.47 Summary

Manhole entry always must be considered a hazardous task due to the potential exposure to chemicals, toxic and explosive gases, physical injury, insects and infectious conditions. Work in manholes can be done safely when the proper procedures are followed.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 171.

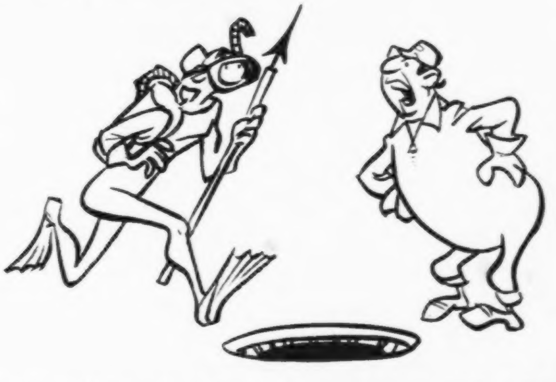
4.4F How can you protect yourself from diseases when working in a manhole?

4.4G How can you protect yourself from insects when working in a manhole?

4.4H How can you protect yourself from drowning when working in a manhole?

4.5 SAFETY EQUIPMENT AND PROCEDURES FOR MANHOLE ENTRY

The pieces of equipment described below are recommended for use when operators are required to enter a collection system confined space.



4.50 Self-Contained Breathing Apparatus (SCBA) (Figure 4.10)

This apparatus consists of a face mask respirator and hose to the air supply. Air may be supplied either from a tank carried on the operator's back or from larger cylinders placed at a convenient location and not carried around by the operator. Cylinders not carried by operators limit movement and connecting hoses can become entangled with other gear. Use when ventilation is unable to provide a

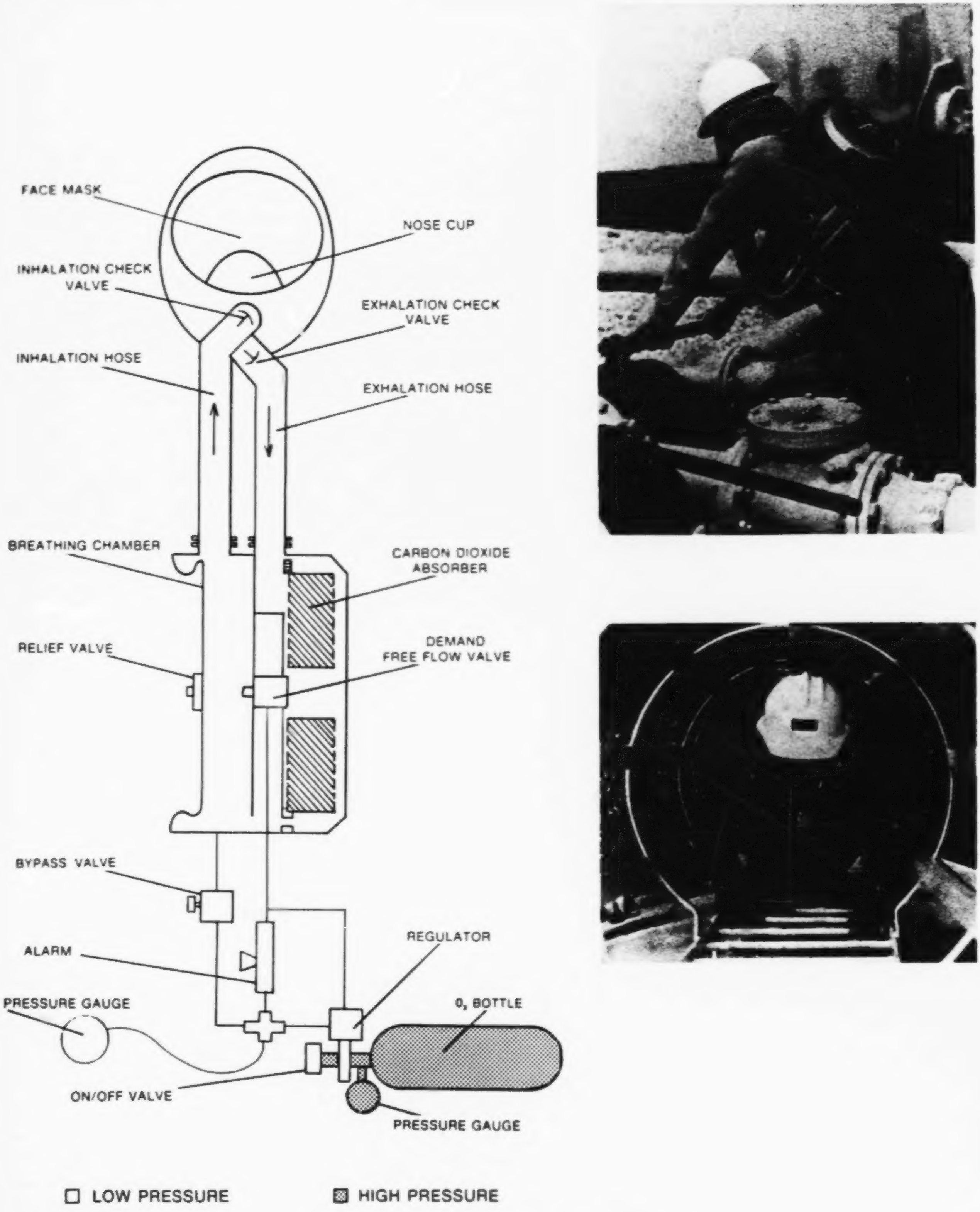

FACE MASK
NOSE CUP
INHALATION CHECK VALVE
EXHALATION CHECK VALVE
INHALATION HOSE
EXHALATION HOSE
BREATHING CHAMBER
CARBON DIOXIDE ABSORBER
RELIEF VALVE
DEMAND FREE FLOW VALVE
BYPASS VALVE
REGULATOR
ALARM
PRESSURE GAUGE
O_2 BOTTLE
ON/OFF VALVE
PRESSURE GAUGE
☐ LOW PRESSURE
▨ HIGH PRESSURE

Fig. 4.10 Self-contained breathing apparatus

(Permission of BioMarine Industries, Inc.)

suitable atmosphere in a manhole or confined space. Remember that if you have air tanks on your back, you cannot be pulled through most manholes.

An established part of your confined space policy should specify that only under extreme circumstances should the collection system operator work in a confined space when the atmosphere presents an immediate danger to life or health. In other words, if you are getting an atmospheric alarm condition, get out and stay out until the condition is cleared. There may be rare occasions when an operator cannot avoid working in a confined space under these circumstances, and therefore, self-contained breathing apparatus must be used. In general, though, the self-contained breathing apparatus (SCBA) will be used by rescue personnel and, therefore, should be readily available when working in a confined space.

Any person that may be expected to use a self-contained breathing apparatus should have a medical examination and test to determine their ability to safely use this equipment. These people must be properly trained and regularly practice rescue operations while wearing a SCBA. If an operator must work in a confined space under hazardous conditions, the operator must wear a SCBA. Rescue workers must be standing by wearing SCBAs so that any unexpected rescue operation can *BEGIN IMMEDIATELY* and *BEFORE THE STRICKEN PERSON IN THE CONFINED SPACE DIES.*

Figure 4.10 illustrates a 60-minute self-contained breathing apparatus which is lightweight, portable, and allows the operator to enter and exit small-diameter manholes. When purchasing SCBAs, be aware that in some cases it may be impossible to enter or exit a manhole wearing this type of equipment and so it would be useless in a rescue operation.

As a possible alternative to SCBAs, many agencies require the operator to have a 5-minute escape air pack in the confined space. This provides a 5-minute supply of compressed breathing air when activated to escape.

4.51 **Safety Harness with Lifeline, Tripod and Winch** (Figure 4.11)

Whenever anyone must enter and work in a manhole or other confined space, a safety harness with a lifeline must be worn. The harness and lifeline may be used to lower an operator into a confined space. Whenever an operator is underground (in a manhole), one operator must remain topside observing the actions of the operator in the harness. A third person must be nearby because two people will be required to pull an unconscious operator out of a manhole.

A parachute-type harness such as the one shown in Figure 4.11 is recommended because it will prevent a limp body from falling out of it. It is important that the lifeline connection attach at the shoulders so as to suspend the body in an upright position. Not only is it difficult to maneuver a tilted or doubled-over body through the 24-inch manhole opening, but you could easily injure a person who is being removed in such a position. Figure 4.12 illustrates a parachute full-body harness with D rings located on the shoulder to facilitate removal of an unconscious operator.

A winch is usually used to raise or lower an operator wearing a safety harness. Truck-mounted retrieval systems like the Davit-type in Figure 4.13 are commonly used, but newer, lightweight retrieval systems are becoming increasingly popular. They are portable, easy to set up and transport from one area to another, and they provide a method for retrieval of an operator from a manhole with only one person above. Figure 4.14 illustrates such a device. This one uses a triple braking system, a two-speed winch, is corrosion resistant, has 120 feet of cable capacity, a level-wind cable device and a maximum capacity of 350 pounds. The tripod is adjustable with safety chains and rubber safety shoes, and weighs 110 pounds.

Figure 4.15 illustrates a variation of this device which is a tripod combination with a retractable steel cable safety block and a manual retrieval winch (come-along). The safety block is used as a fall prevention device. When a fall occurs, inertia activates the block to prevent a free fall. The come-along enables a single crew member on the top to retrieve an unconscious person.

No matter what specific type of tripod you use, remember that the tripod must be properly centered over the manhole opening so a person can be lifted up and out of the manhole without the person touching the rough surfaces of the manhole ring.

4.52 **Portable Atmospheric Alarm Unit (Figure 4.16)**

An atmosphere alarm unit should continuously sample the atmosphere from a manhole and test it for the presence of explosive or flammable gases, toxic gases (hydrogen sulfide) and the percentage of oxygen. One type of unit withdraws air from the manhole for testing; another type is equipped with a sensor or probe that can be lowered into the manhole. The device should have an audible and visible alarm that will warn when flammable gases (such as methane, CH_4) exceed 20 percent of the lower explosive limit (LEL), when hydrogen sulfide concentration exceeds 10 ppm, or when the oxygen percentage drops below 19.5 percent. Battery operated units also should have an alarm to indicate low battery power before such power becomes inadequate for proper functioning. Gas testing devices must be maintained and in proper operating condition at all times. Be sure these devices receive regular calibration and preventive maintenance by a qualified person.

Atmospheric alarm units should have the following features:

1. Portable and battery operated;
2. Continuously and simultaneously monitor for toxic and flammable gases as well as oxygen deficiency;
3. Audible and visible ALARMS for each hazardous condition detected (operators in a manhole should not have to read meters nor decide if a hazardous condition exists—when an alarm sounds or flashes, GET OUT NOW);

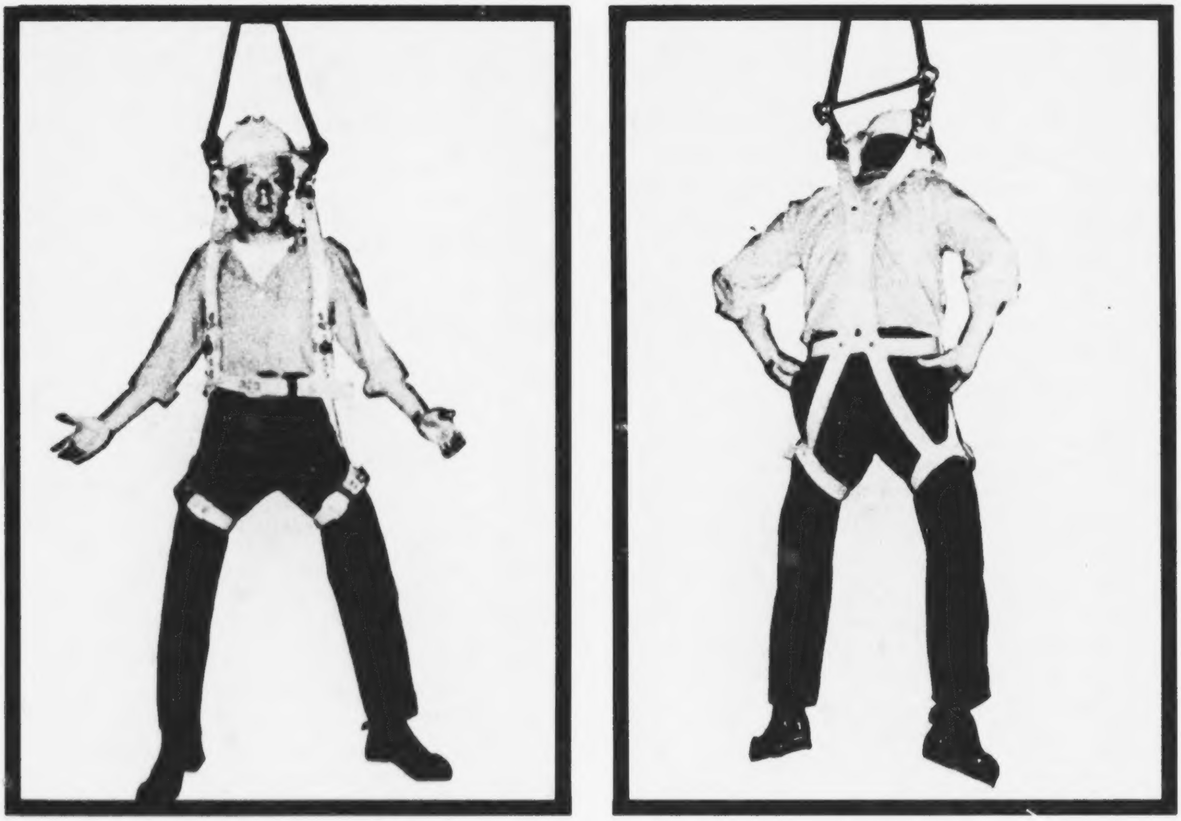


Fig. 4.11 Safety harness with lifeline
(Permission of Miller Equipment Division, ESB Incorporated, Franklin, Pennsylvania)

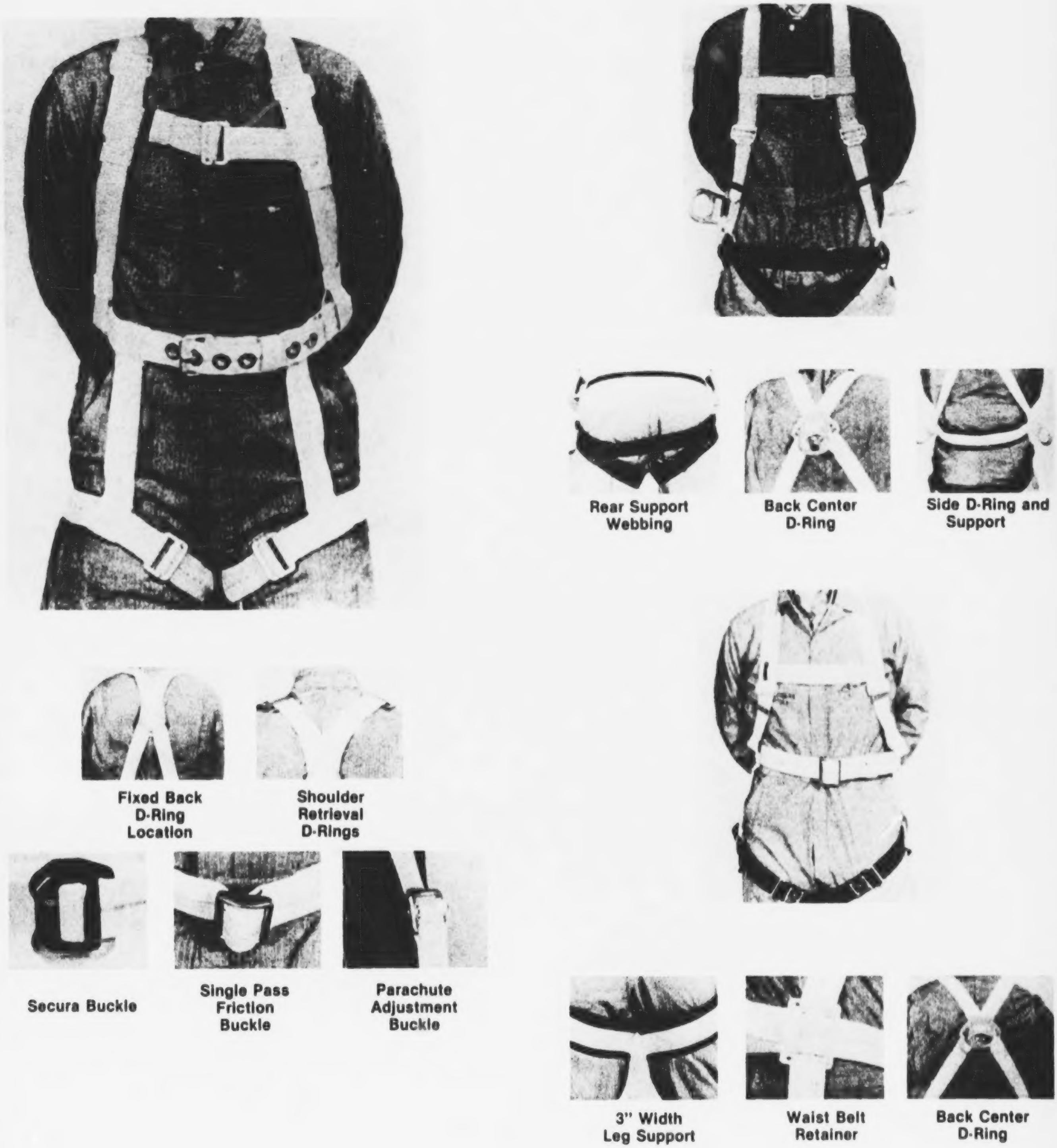

Rear Support Webbing
Back Center D-Ring
Side D-Ring and Support
Fixed Back D-Ring Location
Shoulder Retrieval D-Rings
Secura Buckle
Single Pass Friction Buckle
Parachute Adjustment Buckle
3" Width Leg Support
Waist Belt Retainer
Back Center D-Ring

Fig. 4.12 Full-body parachute harness with shoulder "D" rings

(Permission of DBI/SALA)

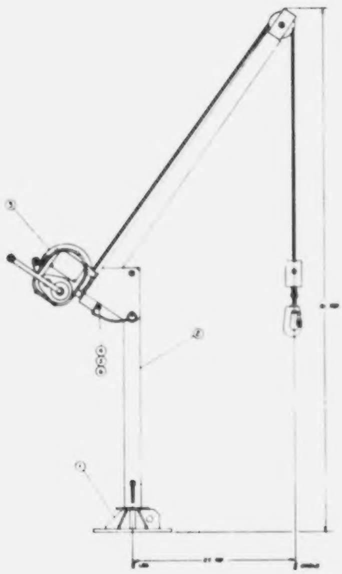


Fig. 4.13 Vehicle-mounted Davit-type winch
(Permission of DBI/SALA)

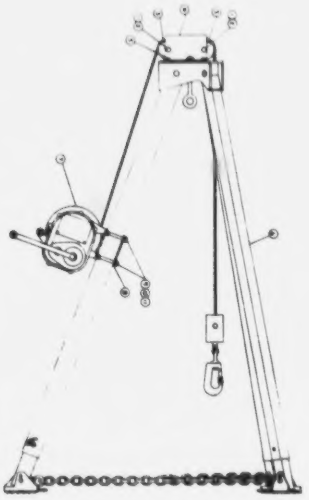


Fig. 4.14 Tripod with two-speed winch
(Permission of DBI/SALA)

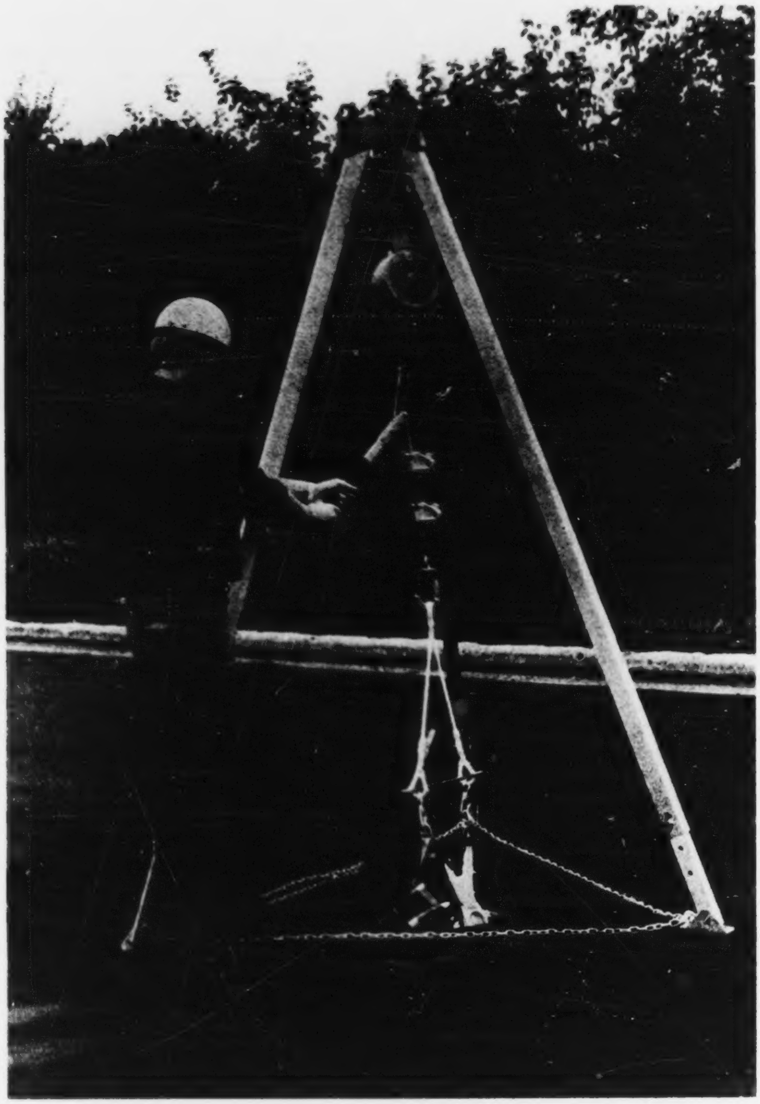
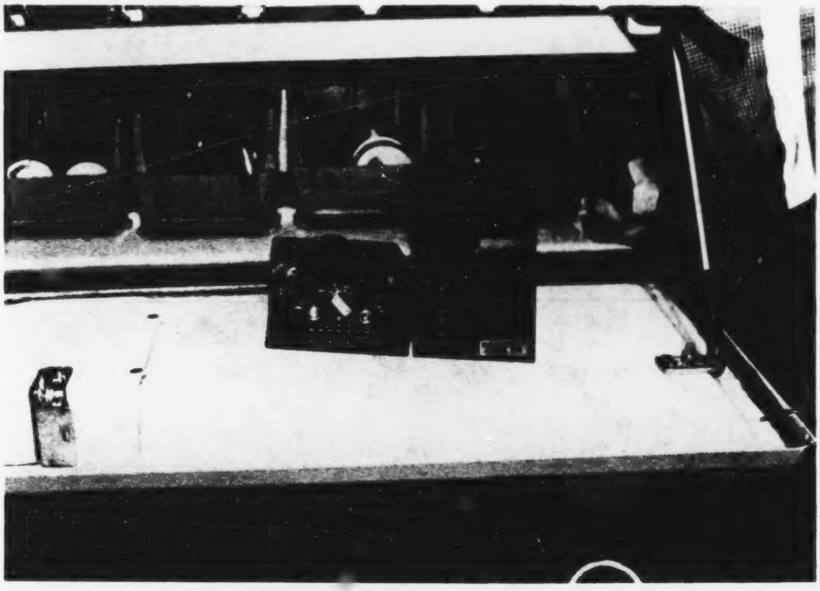


Fig. 4.15 Tripod with safety block and come-along
(Permission of DBI/SALA)



Oxygen/explosive monitor on left
Hydrogen sulfide monitor on right

Fig. 4.16 Portable atmospheric alarm unit

4. Illuminated indicator to signify that the unit is operating;
5. Small enough and light enough to be worn by an operator in a manhole;
6. Over ten hours of continuous operation on one full battery charge;
7. Automatic audible and visible low battery alarm;

8. Remote sample hose and aspirator (to test atmosphere by collecting sample through the holes in a manhole cover); and
9. Gas test kit to calibrate atmospheric alarm.

TOXIC:	More than 10 ppm hydrogen sulfide (H_2S).
FLAMMABLE:	More than 20 percent of the Lower Explosive Limit (LEL) of methane (CH_4).
OXYGEN:	Less than 19.5 percent by volume.

Follow test kit manufacturer's recommendations regarding procedures and frequency of kit calibration and preventive maintenance.

Within the last ten years, advances in microelectronics and sensing elements have drastically improved testing instruments. Previously, instruments tended to be very large, bulky, cumbersome, sensitive to temperature changes or other ambient (surrounding) conditions, and frequently unreliable. Technological advances in instrumentation have produced a number of instruments without the limitations of the early equipment. Many such instruments are readily available to collection system operators.

The most important thing to keep in mind when using instruments in confined space work is the following:

> *ATMOSPHERIC TESTING EQUIPMENT IS JUST ONE TOOL YOU USE AND SHOULD NOT BE CONSIDERED THE ULTIMATE TEST. INSTRUMENTS ARE NOT 100 PERCENT RELIABLE; THEY CAN FAIL OR GIVE ERRONEOUS READINGS. THEY SHOULD NOT, REPEAT SHOULD NOT, PRECLUDE THE USE OF VENTILATION OF SOME SORT IN THE CONFINED SPACE, BUT RATHER SHOULD BE USED IN CONJUNCTION WITH VENTILATION.*

This section will acquaint you with the basic features of testing/alarm instruments and some important concepts related to their use. Before buying testing/alarm instruments carefully analyze their features and suitability for use in the collection system environment, since reliability and ease of maintenance will vary with the manufacturer.

Operators are concerned with three specific guidelines in the working atmosphere:

1. Oxygen content,
2. Explosive or flammable conditions, and
3. Toxic gases (mainly hydrogen sulfide).

Test instruments are currently available that simultaneously sample, analyze, and alarm all three of these atmospheric conditions. Instruments are also available that test oxygen and explosive conditions only or a single gas instrument which would sample only one condition such as hydrogen sulfide.

Because of the limited access and working space, instruments that sample two or three items simultaneously are more desirable, since they reduce the amount of equipment that must be taken into the confined space. A good practice is to secure the instrument not only with the loop provided by the manufacturer, but with an additional line since the instrument may come out of its case and fall into the flow and be lost unless a secondary safety line is used.

Gas detection kits may be carried by operators working in manholes or left on top of the manhole with a person who monitors the kits. If the kit is left on top, then the person on top must keep the suction hose or wand near the person working in the manhole at all times. The test kit is subject to greater abuse when carried by an operator working in a manhole, but could provide better protection. Leaving the instrument on top makes the person topside closely observe the operators in the manhole while keeping the suction hose or wand near the operator. Also the topside person may be able to hear alarms better than an operator working in a manhole.

The instruments available today are small, lightweight, and rugged, designed for a wide range of operating conditions. They consist of two major elements:

1. The sensing element, and
2. The electronic/alarm indicating section.

THE SENSING ELEMENT:

Most of the portable personal-type instruments produced today have diffusion-type sensing heads, which simply means that the ambient air is allowed to contact the sensor through natural air circulation. An air pump is not required to pump the sample into the sensing area. Diffusion heads are used because they are low cost, rugged, and generally involve simple maintenance.

The sensor head should be easily removable from the electronic section, since they do wear out and require replacement. Most instruments have options available that allow the probe to be dropped into a structure, such as a manhole. This feature will be useful if manhole covers in your system have a pick hole in the cover that will allow a probe to sample the atmosphere prior to removing the manhole cover. However, non-ventilated manhole covers are much more widely used today because of odor considerations and the introduction of storm water through the cover holes. Therefore, it is usually not possible to sample manhole atmospheres prior to lifting the cover.

Some types of sensors are sensitive to humidity, temperature, or toxic conditions. High concentrations of silicone, paint, solvents, and fluorocarbons which are present in treatment plants and lift stations can reduce or, depending on the concentration, render the sensing element useless. "Poison resistant" sensors, a recent development, are now being used to minimize the problem.

CATALYTIC SENSING ELEMENTS: (Used in Explosive Meters)

The sensing elements used in most of the personal instruments operate on the principle of catalytic combustion. They are relatively simple and inexpensive and consist of a sensor filament which is heated electrically. When the filament comes in contact with an air/gas mixture, the gas burns and changes the electrical resistance of the filament, depending on the percentage of the combustible gas in the sample. The microelectronics then convert this electrical information to an audible and a visual indication or alarm.

Physical and environmental conditions can affect the sensors and should be evaluated for application in the collection system before purchasing. Caustic gases, temperature, dirty air, humidity, air velocity, and vibration are all factors which should be considered since they can cause inaccurate gas detection meter readings. Hydrogen sulfide, for example, will "poison" conventional catalytic-type sensors used in the typical explosive meter.

The catalytic sensor has a limited life, and therefore must be replaced periodically.

ELECTROCHEMICAL SENSORS: (Hydrogen Sulfide and Oxygen Meters)

Electrochemical sensors use a chemical reaction to generate an electrical current when hydrogen sulfide comes in contact with the sensing element. The electrochemical reaction is proportional to the level of hydrogen sulfide in the air. The electrical current produced by this reaction is amplified in the electronic circuitry and is sent to the alarm and display indicator. The electrochemical sensor also has a finite life and must be replaced periodically, since it does lose its sensitivity to hydrogen sulfide.

UNDERSTANDING LOWER EXPLOSIVE LIMIT (LEL):

1. When a flammable gas is introduced into the atmosphere, fresh air is displaced until the area is filled with the flammable gas. During the process when the atmosphere goes from a normal atmosphere to one that is 100 percent saturated with flammable gas, three specific conditions occur (refer to Figure 4.8, page 131, illustrating Lower Explosive Level). These conditions are:
   a. The atmosphere is too lean to initiate an explosion if a spark or some other ignition source is introduced (not enough flammable gas in the mixture);
   b. The air/gas mixture is in the range where an explosion will occur if an ignition source is present; and
   c. The atmosphere is too rich to result in an explosion, even if an ignition source is present.

NOTE: All sensing instruments should be classified for use in Class I, Division I areas, as specified by the National Electrical Code (NEC). For further information about the classification of areas, see the section on "*EXPLOSIVE ATMOSPHERES*" on page 158.

Instruments should be constructed and rated as "intrinsically safe" which means any arcing or sparks generated in the electrical circuits will not have sufficient energy to initiate an explosion in a combustible or explosive atmosphere.

Alarm Set points
20%
19 to 21 %
10%
AIR/GAS
10 Parts Per M
16% O.L.
EL 170 to 300 PPM
NEC

ALARM SET POINTS:

Explosive meters are calibrated in percent of the LEL as shown on Figure 4.8. Most instruments have adjustable alarm set points. That is, you can determine the level at which the alarm will be activated. While the OSHA standard of 20 percent is the minimum recommended, it is not unusual for agencies to select 10 percent as an internal standard for explosive atmospheres. This allows the collection system operator time to evaluate the confined space when an alarm condition occurs, rather than waiting until the atmosphere does become explosive. The instrument should also indicate other alarm conditions including low battery or other failure conditions.

Similarly, 10 parts per million is generally accepted as the alarm set point for hydrogen sulfide. The maximum concentration that can be inhaled for one hour is 170 to 300 ppm. (Manufacturing Chemists Association. Safety data sheet SD-36.) Death may occur rapidly through exposure to hydrogen sulfide at concentrations above 600 ppm for 0.5 to 1 hour.

Typical alarm set points for oxygen content are 19 to 21 percent; 16 percent is the lowest oxygen level which will sustain consciousness. All alarm set points are selected to allow operator evacuation prior to the points at which levels become critical.

CALIBRATION:

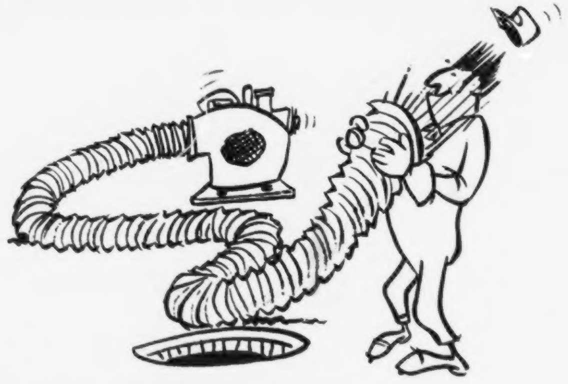
It is extremely important to perform routine calibration before the use of atmospheric sensing instruments, since the electronics are susceptible to drifting. In addition, the sensors do have a limited "shelf life," and will only function for a certain period of time regardless of whether the device is being used or stored. This period may range from several months to a year so even unused sensors may not be operable if stored for longer periods of time. Instruments should allow a sensor change without returning the entire unit to the manufacturer where it would be unavailable for several weeks.

Calibration kits are available and should be purchased along with the equipment. These kits contain a small gas cylinder with an accurately measured percentage of gas; for example, 2.5 percent methane and 17 percent oxygen. In addition, an adapter is provided which allows the gas to be injected into the sensor head.

ELECTRONIC SECTION:

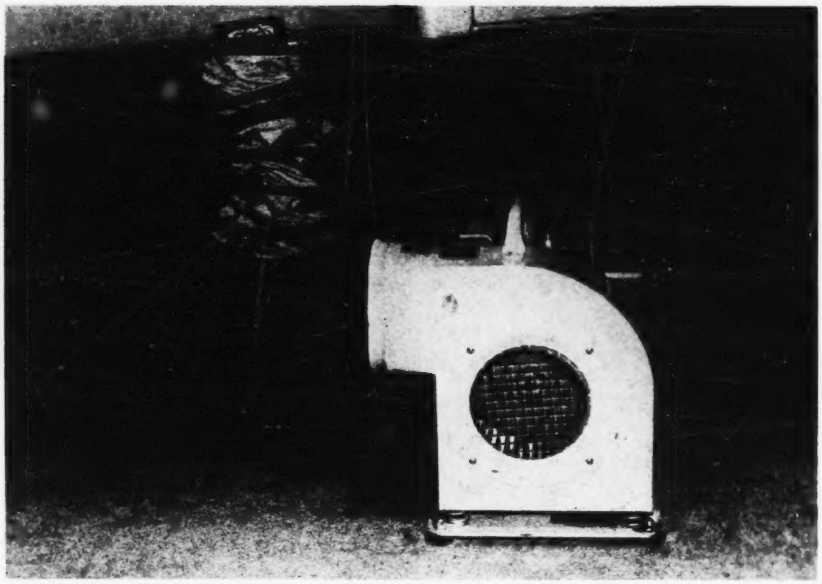
The electronic section contains the microelectronic circuitry including a microprocessor and the audio and visual alarms. Typically visual alarms are Light Emitting Diode (LED) readouts in one or more colors, or a single LED display that lights up when the alarm set point is reached. The display may also indicate actual level in ppm using a liquid crystal display (LCD). Monitors should have an audible alarm feature which is a signal you can hear. It is usually specified as a minimum sound level of 80 dBA at 10 inches to allow you to hear the alarm in a noisy working environment.

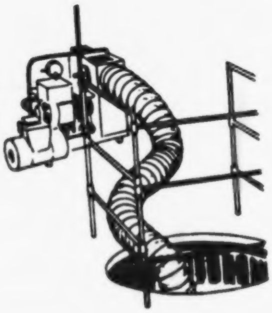
The electronics should be housed in a high-impact, rugged plastic case, classified as intrinsically safe for use in Class I, Division I areas. It is important that the housing be waterproof or at least moisture-resistant, since that is the type of environment where you will use them. The instrument should not be left overnight in vehicles, particularly if you are in an area where it is cold, since temperature can affect the sensors and the battery. The instrument should be returned each night to the shop. If standard batteries are used, they should be checked and replaced. If rechargeable batteries are used, the instrument should be placed on the charger so it is ready for use again the following day.



4.53 Ventilation Blower with Hose (Figure 4.17)

Before entering a manhole, run the ventilation blower for at least 10 to 15 minutes with the hose outlet positioned all the way down to the bottom of the manhole. A fan-type blower driven by an electric motor or truck power should have between 750 and 850 CFM capacity to adequately ventilate a standard manhole with a 4-foot diameter at the bottom. The standard unit will have a 15-foot long hose, eight inches in diameter, to conduct the blower air to the bottom of the manhole. Hose couplings and extensions must be available because some manholes are over 30 feet deep. Gasoline engine-powered blowers are less desirable due to the high noise factor and the possibility of producing undesirable fumes and gasoline leaks. Some agencies use blowers powered by bottled gas. One problem encountered in using blowers is that blowing air into a manhole can create pockets of gas. Ventilation can be improved by removing the nearest upstream or downstream manhole cover.





NOTE: Air inlet should be at least two feet above the street level so street trash will not be picked up by the flowing air.

Ventilation of a manhole

Fig. 4.17 Ventilation blower with hose

Another approach is to draw air from the bottom of the manhole. This method is acceptable if the new air that flows into the bottom of the manhole is satisfactory for breathing and does not contain flammable or toxic gases. If there is an air space in the downstream pipe, air may be exhausted or drawn from the downstream manhole. Thus, the person in the manhole is breathing fresh air from the manhole entrance.

4.54 Manhole Enclosure (Figure 4.18)

An enclosure is sometimes set up around an open manhole to prevent unauthorized persons from endangering the operator in the manhole or from falling in themselves. This structure should be of adequate strength to support the weight of an operator when required. Do not use an enclosure if it interferes with the work of a crew or their safety.

Some agencies use a "toe board" in addition to the enclosure. This is a metal ring which fits into the manhole frame and extends a minimum of four inches above the ground. These devices prevent objects from rolling into the manhole and provide protection against people walking into an open manhole.

4.55 Ladders and Tripods

Lightweight aluminum-alloy extension ladders are often used in shallow manholes. They are easy to handle and to climb. Many operators use strap or rope ladders with rigid metal or rope rungs. These ladders are lightweight, do not require firm bottom support (suspended from the top), and are quickly installed and removed with little danger to the operator in the manhole. Tripods with winches are used by some agencies to avoid the use of ladders or steps in manholes, wet wells and other below-ground enclosures, especially deep manholes.

4.56 Ropes and Buckets

Tools for use by operators in a manhole must be lowered to them and recovered from them by the use of a bucket. Lower the bucket using a hook rope with a safety clasp that will swivel. Dropping tools for operators to catch and allowing operators to toss tools out has resulted in many injuries and should result in immediate warning or dismissal of the guilty operators.

4.57 Hard Hats

No person should be allowed to enter a manhole without adequate head protection. The full-strength hard hat is recommended. The brim should be adequate to protect the nose or a clear face shield should be used. Chin straps are almost a necessity in confined or close quarters.

4.58 Protective Clothing

As much of a person's skin as possible should be covered with clothing that will prevent scrapes and abrasions. No one should ever be permitted in a manhole that has once been in service unless fully clothed with shoes, gloves and long sleeves. Selection of clothing depends on actual working conditions such as the temperature and the job to be done. Gloves are usually recommended, but some people prefer not to wear gloves because they get wet and wastewater can run down your arms when working. Whether gloves are worn or not, always thoroughly clean your hands *BEFORE* smoking, eating, or leaving the job site. Cleaning can be accomplished using waterless soap and paper towels. Clothing should be provided for collection system operators, including shoes with steel toes. If boots are worn, the slip-on type of knee-length rubber boots are recommended because they are relatively easy to wash off and remove. As previously mentioned, it is advisable to have work clothes commercially laundered for the protection of operators and their families.

4.59 Other Equipment and Procedures

1. *CONES, BARRICADES AND HIGH-LEVEL FLAGS:* When working in areas near moving traffic, always use cones, barricades and high- level flags to warn motorists of your presence and to protect yourself. A utility truck is an effective barricade. This equipment and its proper application is discussed in Section 4.3, "Routing Traffic Around Job Site."
2. *FIRST-AID KIT:* A suitably equipped first-aid kit should be on hand and immediately available for use where operators will be working in manholes. Artificial respiration tools and devices are essential parts of this kit. Eye washing solutions as well as the irrigation or rinsing eye cups should be included. If crews must work in areas where they could come in contact with poison ivy or poison oak, solutions to relieve itching are essential. At least one or more crew member should be trained in the use of first-aid equipment and procedures, including CPR (cardiopulmonary resuscitation).

3. *FRESH WATER, SOAP AND CLEAN CLOTHES:* After leaving a manhole, a strong soap and clean fresh water should be available to an operator for washing hands and face. Waterless antiseptic hand cleaners also are effective and approved for washing purposes. Paper towels may be used for the wiping process. This is very important if the operator smokes or is going on a lunch or coffee break. Clean clothes should be put on after working in a manhole.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 171.

4.5A List the safety equipment recommended for use when operators are required to enter a manhole.

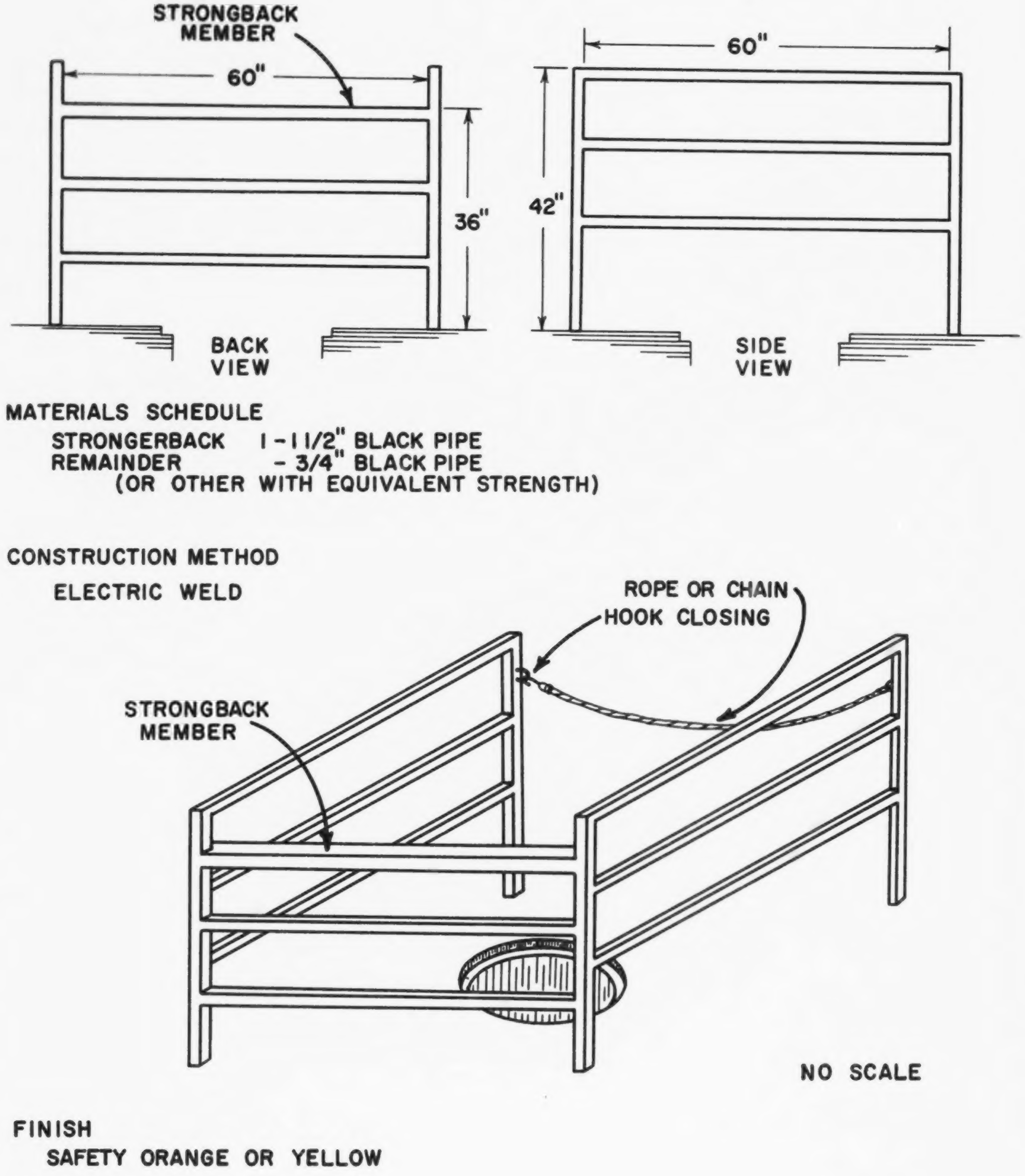
4.5B Describe the most important features of a gas detection device that would be used when entering a manhole.

4.5C What toxic gas is commonly found in wastewater collection systems?

4.6 FINAL PRECAUTIONS BEFORE MANHOLE ENTRY

4.60 Health Conditions of Operators

Any operator entering a manhole should conform to the following rules at the time of entry:


STRONGBACK MEMBER
60"
36"
BACK VIEW
60"
42"
SIDE VIEW
MATERIALS SCHEDULE
STRONGERBACK 1 - 1 1/2" BLACK PIPE
REMAINDER - 3/4" BLACK PIPE
(OR OTHER WITH EQUIVALENT STRENGTH)
CONSTRUCTION METHOD
ELECTRIC WELD
ROPE OR CHAIN
HOOK CLOSING
STRONGBACK MEMBER
NO SCALE
FINISH
SAFETY ORANGE OR YELLOW

NOTE: Strongback member and both sides should be coupled together so they can be stacked for transportation and quickly assembled if needed.

Fig. 4.18 Typical portable manhole safety enclosure

1. Be in good health. If you are recovering from a recent illness or surgery, do not enter a manhole until fully recovered.
2. Be in sound physical condition.
3. Be completely free from the influence of alcoholic beverages or drugs and from the impairment of a hangover.
4. Have no open sores, skin irritations (including such problems as poison oak), fungus infection (athlete's foot for example) or serious sunburn.
5. Have current immunizations. Operators in a wastewater collection system should have current immunizations against illnesses and diseases which might be encountered in the collection system. Many agencies require typhoid and tetanus shots with booster shots every five years as a matter of policy. Contact your safety officer or personal physician for recommendations.

Operators who do not require corrective glasses for manhole tasks are preferred for such work. Other operators on a manhole entry crew also should be in good health with necessary physical capacities to accomplish required work.

4.61 Required Tools, Materials, Equipment

Before sending an operator into a manhole, carefully inventory and examine the condition of all required tools, materials and equipment needed for the work. Exposure to injury is greatest while an operator is descending into or climbing out of a manhole. Therefore, job organization and equipment should be arranged to permit all work to be accomplished with a single entry and exit of the manhole.

4.62 Briefing

Just prior to entry, the foreman or crew leader should hold a short briefing on the project to explain the work sequence and the safety rules that must be observed. All members of the crew should be fully informed of all aspects of the project and procedures that will be followed in event of any emergency.

Many agencies require that a confined space entry form (Figure 4.19) be completed and signed before manhole entry to ensure that all of the necessary safety checks have been performed.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 171.

4.6A What are some of the health conditions of operators that should be considered before entering a manhole?

4.6B What topics should be discussed during the briefing before manhole entry?

4.7 PROCEDURES DURING MANHOLE ENTRY

There is no single procedure, instrument, or method which will provide full protection in a manhole entry situation, but rather a combination of factors. Many agencies have discovered new ways of doing collection system maintenance and minimizing entry (and therefore risk) into manhole and underground spaces. Collection system operators are among the most innovative people in the world. Special long-handled hooks, grapplers, and other tools have been fabricated to remove debris and install equipment without entering a manhole.

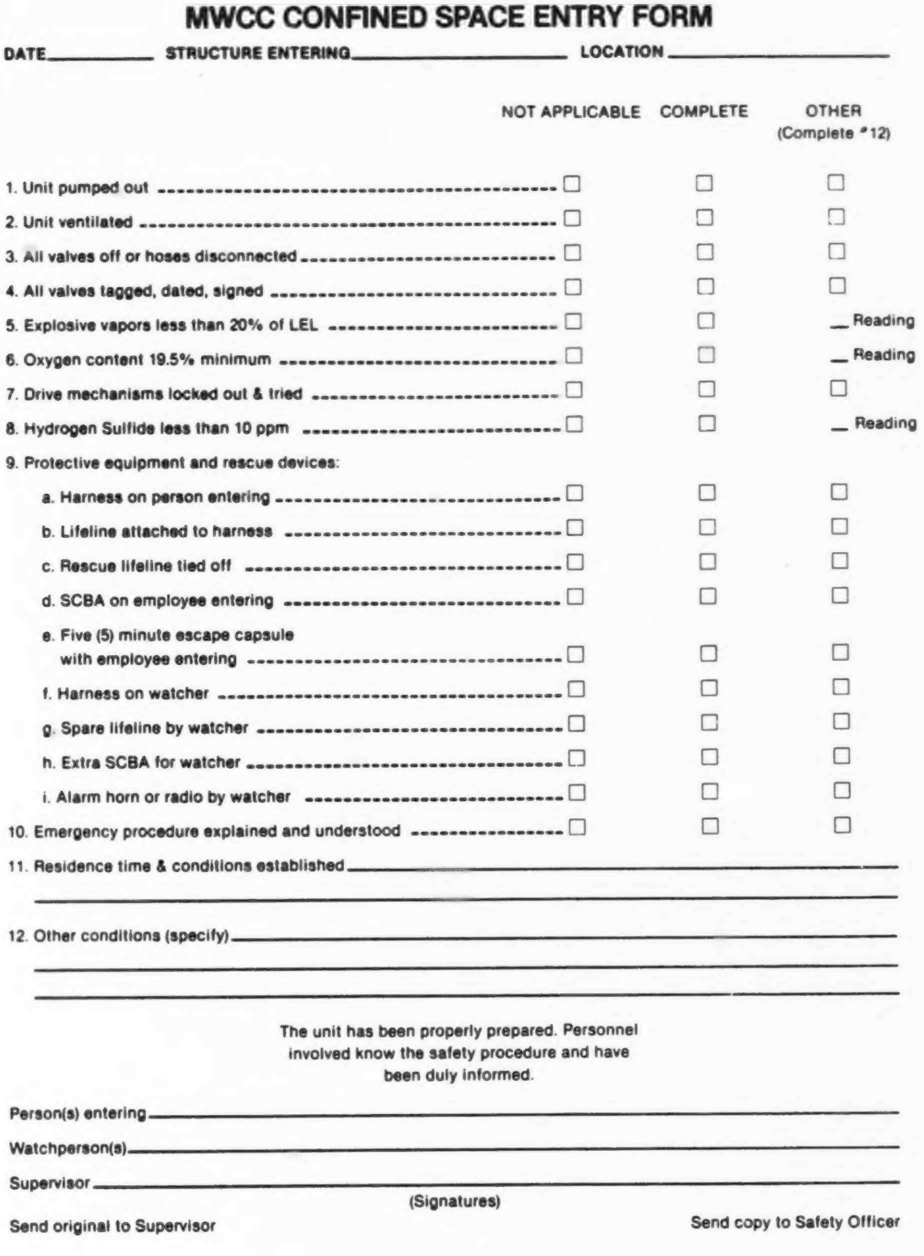
A well planned maintenance program also helps reduce risk since it identifies over-maintained sewers where routine bucketing or cleaning operations may not be necessary and, if reduced, will lower the number of times operators must enter manholes.

In any case, it will not be possible to eliminate entry and work in confined spaces 100 percent of the time. Therefore, a confined space work procedure must be established. The following is a suggested procedure which one agency developed to meet the needs of their collection system operators. In some cases, this procedure may not meet your state or local requirements. The purpose of including these procedures here is to provide you with the essential elements of an workable procedure.

4.70 Confined Space Work Procedures

Whenever it is necessary to enter a confined space, the following procedure shall be adhered to:

1. A confined space entry form (Figure 4.19) shall be used to review the necessary precautions and conditions prior to entry. This form must be fully completed and understood by each employee involved with the job task.
2. All traffic control measures shall be taken.
3. All valves or applicable power sources shall be locked out.
4. An initial test of the atmosphere must be performed to assure that the oxygen content, toxic gases and explosive vapors are at acceptable levels. Unacceptable levels will result in an alarm from the instrument. Important steps include:
   - a) All instrumentation shall be properly calibrated before each use in accordance with manufacturers' instructions;
   - b) Careful attention should be given to following the operating instructions that accompany every instrument;
   - c) If an "alarm condition" develops, the area shall be evacuated, ventilated and retested;
   - d) Ventilation shall not be considered a substitute for testing a confined space;
   - e) The fresh air intake on ventilation equipment shall not be placed in a contaminated area (for example, avoid an area with engine exhaust which will produce carbon monoxide);
   - f) Fresh air shall be continuously circulated as long as the confined space is occupied.



MWCC CONFINED SPACE ENTRY FORM

DATE__________ STRUCTURE ENTERING____________________ LOCATION____________________

	NOT APPLICABLE	COMPLETE	OTHER (Complete #12)
1. Unit pumped out	☐	☐	☐
2. Unit ventilated	☐	☐	☐
3. All valves off or hoses disconnected	☐	☐	☐
4. All valves tagged, dated, signed	☐	☐	☐
5. Explosive vapors less than 20% of LEL	☐	☐	__ Reading
6. Oxygen content 19.5% minimum	☐	☐	__ Reading
7. Drive mechanisms locked out & tried	☐	☐	☐
8. Hydrogen Sulfide less than 10 ppm	☐	☐	__ Reading
9. Protective equipment and rescue devices:			
a. Harness on person entering	☐	☐	☐
b. Lifeline attached to harness	☐	☐	☐
c. Rescue lifeline tied off	☐	☐	☐
d. SCBA on employee entering	☐	☐	☐
e. Five (5) minute escape capsule with employee entering	☐	☐	☐
f. Harness on watcher	☐	☐	☐
g. Spare lifeline by watcher	☐	☐	☐
h. Extra SCBA for watcher	☐	☐	☐
i. Alarm horn or radio by watcher	☐	☐	☐
10. Emergency procedure explained and understood	☐	☐	☐

11. Residence time & conditions established________________________________

12. Other conditions (specify)________________________________

The unit has been properly prepared. Personnel involved know the safety procedure and have been duly informed.

Person(s) entering________________________________

Watchperson(s)________________________________

Supervisor________________________________

(Signatures)

Send original to Supervisor

Send copy to Safety Officer

Fig. 4.19 Confined space entry form

(Permission of Metropolitan Waste Control Commission, Twin Cities Area, St. Paul, Minnesota)

5. All persons who enter a confined space shall be instructed (by their immediate supervisor) as to the nature of the hazards involved, the necessary precautions to be taken, and in the use of protective and emergency equipment required as approved by the Safety Officer.

6. All persons entering a confined space shall carry a five (5) minute escape capsule. The use of a Self-Contained Breathing Apparatus (SCBA) shall preclude this requirement.

7. All persons entering a confined space shall wear a rescue harness with attached lifeline. Any variation of this requirement shall be approved by the area manager/plant manager prior to entry.

8. No smoking shall be permitted inside or within ten feet (10 ft) of a confined space.

9. At least one person shall remain outside the confined space while it is occupied. This person's job task shall be that of a watch person and to maintain communications with employee(s) inside the confined space. This person shall remain at the entrance of the confined space as long as it is occupied.

10. Atmospheric testing shall continue while the confined space is occupied.

11. All persons in a confined space shall vacate immediately if the warning alarm on any instrument is activated.

12. A hard hat shall be worn at all times in a confined space.

13. If a necessary piece of equipment is in need of repair or missing, work shall be halted until replaced or repaired.

14. Hot work shall not be permitted if the atmosphere contains explosive gases greater than 10 percent LEL (Lower Explosive Limit). The definition of hot work as used in this procedure includes, but is not necessarily limited to, burning, welding, brazing, soldering, cutting, heating, grinding, drilling, sanding, and chipping.

15. Any hazardous condition encountered shall be entered on line 12 of the Confined Space Entry Form (Figure 4.19) for future reference (e.g., steps in manhole are in poor condition).

The actual field form is a ledger-sized (5½" x 8½") two-part carbonless form which is completed each time a confined space is entered. Copies of the form are kept on file, with one copy sent to the Safety Department for their file. The forms are pre-punched and carried by each crew in a ledger sized notebook.

Keep in mind that when you and other members of your crew sign this form, you agree to follow the listed procedures. If you then elect not to follow the established procedures and your action results in an injury or fatality, you have assumed the responsibility for your actions (and those of your crew, if you are a field supervisor). You could be held legally liable for the consequences of your actions or those of your crew.

The remainder of this section is an expansion of the "Confined Space Work Procedure."

4.71 Operations of Manhole Entry

The minimum crew required to be present for an operator to enter a collection system manhole is three operators: the operator who will go into the hole, the lifeline and winch attendant and an assistant on the surface. The arrangement of the safety and other equipment is generally accomplished by the entire crew; however, a support crew may be necessary to direct traffic and provide other needed assistance.

1. Place the manhole safety enclosure around the manhole, if necessary.

2. Calibrate the portable explosivity-toxicity-oxygen alarm system *BEFORE* removing the manhole cover. Test the manhole from top to bottom for oxygen deficiency, explosive and toxic (hydrogen sulfide) gases. If possible, test for explosive mixtures before removing the manhole cover because removal of the cover may produce a spark and cause an explosion. Also, it is helpful to know conditions in the manhole before any ventilation occurs.

IF AN EXPLOSIVE ATMOSPHERE IS DISCOVERED IN A MANHOLE:

a. Immediately notify your supervisor that an explosive condition has been discovered and provide as many details as possible, including location. Request notification of police and fire departments and also industrial pretreatment facility inspector.

b. Do not remove the manhole cover.

c. Turn off any running engines in the vicinity that could cause a spark.

d. Route vehicles around manhole using cones, flags and barricades.

e. Inspect upstream and downstream manholes for explosive conditions to determine the extent of the problem.

f. Route traffic off the street to reduce potential for explosion.

g. Notify industrial waste inspectors and wastewater treatment plant operators.

h. Attempt to locate the source of the problem and correct the situation.

i. Cautiously ventilate the system with a large blower to eliminate the explosive hazard. Try ventilating from a safe upstream or downstream manhole in order to keep operators and equipment away from explosive conditions.

j. Be sure there is *NO SMOKING* in the area.

If atmosphere in manhole tests OK, continue with entry procedures.

3. Never use hands to remove or replace the manhole cover. Always use manhole lifts approved by the safety

agency that regulates your activities (Figure 4.20).

4. Open manholes upstream and downstream from the work area to encourage natural ventilation of the sewer. Cover open manholes with grating and place barricades around manholes to warn traffic and pedestrians.
5. Clean the area immediately around the manhole opening, including the manhole ring and lid ledge and remove all loose debris. Sweep the area before removing the manhole cover and clean the ring ledge after the cover has been removed.
6. Before entering the manhole, start the ventilation blower and thoroughly ventilate the manhole atmosphere. The blower should be located in an area upwind of the manhole and at least ten feet from the manhole opening. If the blower has a gas-driven engine, the exhaust must be downwind from the manhole. Place the air intake to the blower from two to five feet above the ground surface, depending on conditions (higher for dusty ground surfaces). Some agencies prefer to exhaust or pull air from the downstream manhole if possible.
7. Once the operator going into the hole has donned the safety harness and had the lifeline attached, the other operator on the crew or the foreman should check it for proper fit and attachment.
8. Continue to use the alarm system to test for the presence of an oxygen deficiency and explosive gases in the manhole atmosphere the entire time the operator is in the manhole.

4.72 While Operator Is in the Manhole

1. The end of the lifeline must be attached to a hoisting device.
2. Whenever an operator is in a manhole, continuously test the atmosphere for oxygen deficiency and for explosive and toxic (hydrogen sulfide) gases. Proper ventilation generally will prevent any problems with the manhole atmosphere from developing except during a chemical spill or dump (discharge) up sewer from the manhole. If the flammable gas level is within only 10 percent of the lower explosive limit (LEL), this is an indication that ventilation is ineffective.
3. The operator in the manhole must be observed continuously by a crew member within the safety enclosure. (Safety enclosures are not considered necessary by some agencies.) This person shall perform no other function, but keep constant watch over the operator in the manhole, and call for help if needed. The operator observing the person in the manhole should be careful to secure any objects in shirt or jacket pockets so that they will not fall into the manhole when bending over it. Also the operator must be careful not to accidentally kick any tools or objects over the edge of the manhole. As long as the operator is in the manhole, the operator topside should carefully watch and not distract the operator in the manhole. Always listen and respond to the needs and condition of the operator in the manhole.
4. If there are any indications of trouble, such as unusual behavior or warning signals from the gas/oxygen alarm system, immediately bring the operator up out of the manhole.

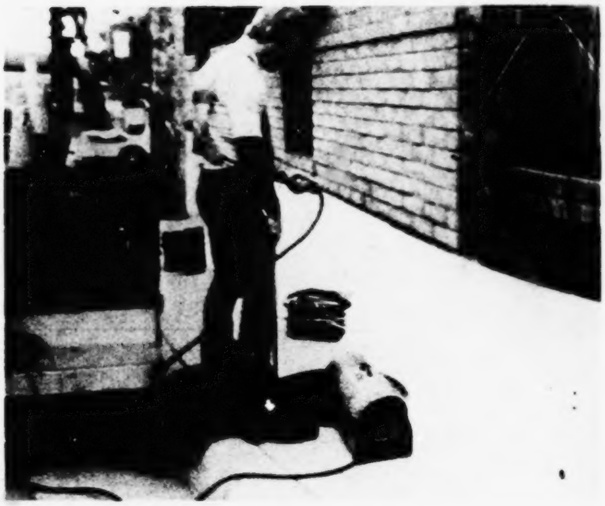


Fig. 4.21 Holding lifeline

How many safety hazards can you spot in Figure 4.21? No gloves, no hard hat, manhole cover balances on curb, manhole cover between operator's legs instead of out of the way, second operator topside missing, safety cones to warn pedestrians missing, and vehicle too close to manhole, thus not allowing adequate working room. A hoisting device should be used. Is the atmosphere in the manhole being tested continuously?

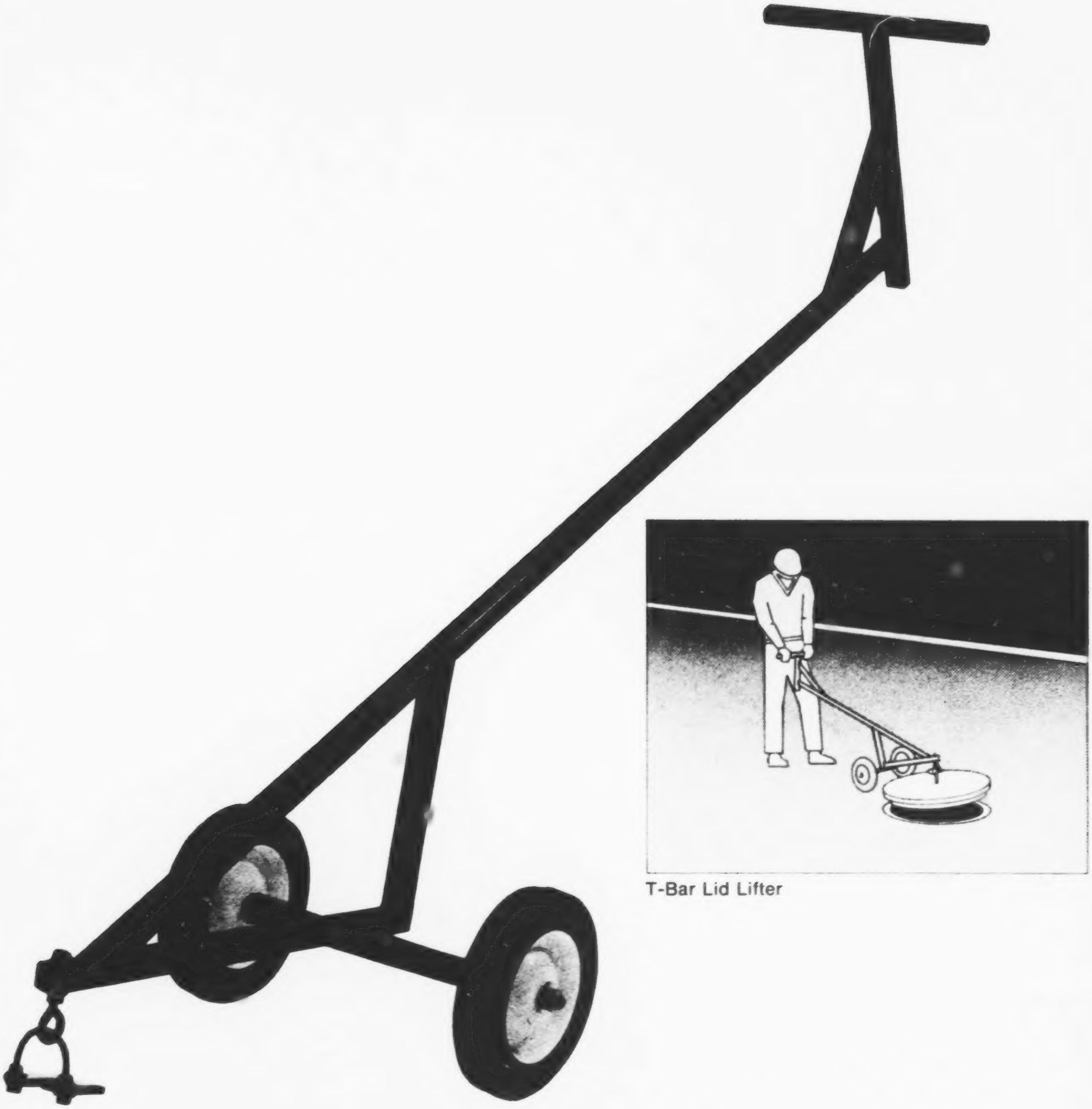
4.73 Special Problems of Manhole Work

1. Manholes are frequently reservoirs for strong odors and many of these odors can cause *OLFACTORY FATIGUE.*[4] This is a condition where a sharp odor or prolonged breathing of an odorous atmosphere will cause the sense of smell to be temporarily lost.

   If a smell of gas or some dangerous substance is noticed when first opening a manhole lid, the lack of such a smell at a later time must never be taken as an indication that the source or danger has been eliminated. Continuously ventilate and test the manhole atmosphere for oxygen deficiency and for explosive and toxic gases whenever someone is in a manhole. Don't depend on odors to provide warnings; but when you do smell a potentially harmful odor (such as hydrogen sulfide), re-

---

[4] *Olfactory Fatigue (ol-FAK-tory). A condition in which a person's nose, after exposure to certain odors, is no longer able to detect the odor.*



T-Bar Lid Lifter

Fig. 4.20 Manhole lid lifter

(Permission of Cherne Industries, Inc.)

check the atmospheric testing system. If your lips tingle or become numb, these are signals to get out of the manhole *NOW.*

2. When the atmosphere in a manhole has been displaced by a gas that has no breathable oxygen in it, life expectancy for anyone entering the manhole is approximately 180 seconds with awareness of a problem lasting less than 30 seconds.
3. A lowering of the oxygen content in the air you breathe can rapidly result in a serious injury. *NEVER* allow anyone to enter a manhole until the oxygen content tests greater than 19.5 percent oxygen. The early warning signs that the topside operator should be looking for include:
   a. Labored breathing (shortness of breath);
   b. Chest heaving, and
   c. Change from usual responses.

   Victims suffering from a lack of oxygen may require artificial respiration if the case is severe. If the victim is still breathing without assistance, pure fresh air is safe and effective.

   WARNING: IF AN OPERATOR IS SUFFERING FROM LACK OF OXYGEN, ONLY AN EXPERT SHOULD ATTEMPT TO REVIVE OR ASSIST THE OPERATOR BY ADMINISTERING PURE OXYGEN. TOO MUCH OXYGEN IN AN OPERATOR'S BLOOD CAN BE AS DEADLY AS TOO LITTLE.
4. Truck-mounted, boom-type hoists are sometimes used for lowering and lifting an operator out of a manhole while the operator is in a safety harness. An electrically operated boom of this type must have a "power kill switch" on the boom that activates automatically when maximum cable length has been recovered by the drum.
5. Any equipment manufactured and sold as safety equipment is required to pass rigid performance and quality tests. Such labels as Underwriters Laboratories and Factory Mutual indicate that the equipment meets those qualifications. Always test equipment under conditions of use to learn how the equipment works and to be assured that it will work when needed.

4.74 After Leaving Manhole

A person who has been in a collection system manhole should take a hot shower and put on clean clothes before leaving work at the end of the day. Under no circumstances should the clothing worn in the manhole be worn home. Never expose your family to any contagious infection that might have come into contact with your clothing. *NO CLOTHING* worn in sewer maintenance or repair work should be worn home or washed with the family laundry.

4.75 Responsibility

The crew leader or foreman has the responsibility to be sure all work is conducted in a safe and prescribed manner. In some states, the person in charge can be held liable and subject to both a fine and imprisonment if damage or injury results from failure to use prescribed procedures. The employer may pay the fine, but the responsible person must serve the time. Every agency must prepare, publish and circulate to the collection system operators safety requirements and procedures for manhole entry.

MANHOLE ENTRY SUMMARY

1. Test for flammable or explosive conditions, toxic gases and oxygen deficiency.
2. If flammable or explosive conditions are discovered, notify supervisors and experts. *DO NOT ENTER.*
3. If toxic gases and/or oxygen deficiency is found, *DO NOT ENTER* unless an emergency/rescue situation exists. Take all necessary safety precautions. Try ventilating area to clear up hazardous atmosphere and retest.
4. If atmospheric conditions test OK, ventilate manhole and monitor conditions continuously while working in manhole. Wear a safety harness and lifeline. Evacuate manhole immediately if conditions change, alarms sound or if you start to feel "different."

FOLLOW SAFE PRACTICES
USE GOOD JUDGMENT AT ALL TIMES

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 171.

4.7A What is the minimum size of a crew when someone enters a manhole?

4.7B What should the operator at the manhole entrance be doing while another operator is in the manhole?

4.7C What is the minimum level of oxygen in air for safe breathing?

4.7D What should an operator do after leaving a manhole?

MILLIAMPS
AMPS
VOLTS
WATTS
OHMS
CIRCUITS
CURRENT FLOW
AMPERES

4.8 ELECTRICAL SAFETY

Collection system operators are routinely exposed to a variety of field conditions related to electrical equipment and hazards. The objective of this section is *NOT* to make you an instant electrical expert qualified to work on the electrical equipment that we have in our systems, but it is to make you more *KNOWLEDGEABLE* so that you have an *AWARENESS* of the hazards concerned with electrical system.

The first rule that applies to electrical systems is *"IF YOU ARE NOT QUALIFIED, DO NOT, UNDER ANY CIRCUMSTANCES, ATTEMPT TO WORK ON ELECTRICAL SYSTEMS."*

Let's take a look at some of the types of equipment and work situations that increase our exposure to electrical hazards:

1. Lift Stations have a variety of electrical systems, single phase, three phase, alternating current (AC), direct current (DC), low voltage and medium voltage;
2. Flow Metering Stations, usually wet locations, may require explosion-proof wiring methods;
3. Alarm Telemetry Systems;
4. Standby/Emergency Power Equipment;
5. Voltage ranges from low to high, voltages range from 24 volts to 4,160 volts, and as high as 13,800 volts (typical exposure is in the 120 volt to 480 volt range);
6. Much of our equipment is located in wet and/or damp locations;
7. We frequently have to work under adverse conditions such as thunderstorms, where downed power lines are frequent hazards.

8. Failures occur frequently at night when it is dark;
9. We may be required to provide standby power through the use of portable generators and temporary wiring;
10. When working under emergency conditions, time is usually very limited. In order to prevent bypassing of raw wastewater or backups into private homes, we are under a great deal of pressure to rig pumps, generators or other equipment; and
11. Construction repair projects increase the hazard of encountering live underground power lines.

These hazards increase the possibility of:

- Electrocution resulting in slight to serious burns or even death;
- Physical injury due to failure to lock-out or disconnect electrical systems, for example, someone starts a pump while you have your hand in the impeller cleaning out rags;
- Explosions resulting from electrical equipment operating in explosive atmospheres, such as wet wells and underground vaults;
- Protective equipment such as circuit breakers exploding due to high short circuit currents; and
- Temporary or permanent blindness due to flashing or arcing.

To further increase your understanding of electrical systems, which many operators view as mysterious, we can compare it to a hydraulic system consisting of a pump, a pipeline, and a valve.

1. Referring to Figure 4.22, water pressure is equal to the voltage.
2. The water, which is the movement of water molecules, is equal to current, which is the movement of electrons. In either case, we are moving physical things or material.
3. The valve is equal to the resistance. If you close down the valve, you increase the resistance and reduce the ability of the water to move. Similarly, resistance in an electrical system is a blockage of the movement of electrons. In electrical systems this resistance is usually the "load" which may take the form of motor windings in an electric drill, a light filament, or even a human body.

In the case of the electrical system, the power company or utility can be compared to the pump. It supplies the electrical energy just as the pump supplies hydraulic energy to the pipeline.

Other similarities exist in the hydraulic system/electrical system. Both of these systems want to become "closed loop." In other words, in an electrical system the electrons (current measured in amps, milliamps, or microamps) want to return to the source which is commonly referred to as ground (at a zero voltage state). In the case of the hydraulic system, the pressure in the pipe also wants to return to a zero pressure state. When you open a closed, pressurized pipeline, the pressure will want to drop to zero if the pump is off.

The significance of this, in collection system work, is that when we use the human body to become the "load," current is allowed to flow through the body to return to its ground state. The amount of current that flows through the human body influences the amount of damage to our body.

Many misconceptions exist about electricity. Among the more common is that low voltage (120 volts) is less dangerous than a higher voltage (240 volts, 3 phase or 480 volts, 3 phase). In fact, it is the current flow (electrons) through the body that causes the problems. The amount of current flowing through the body depends on the voltage and the resistance and can be expressed in the following formula:

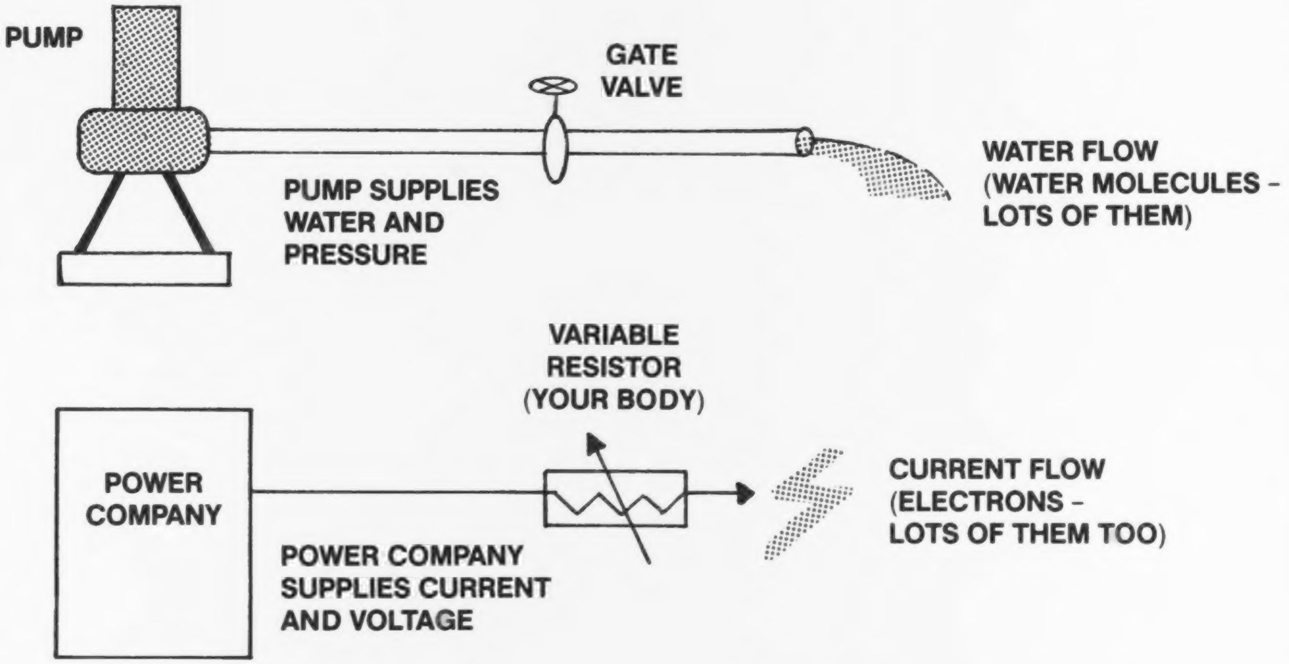
Amps are equal to voltage divided by resistance.

$$\text{Current, amps} = \frac{\text{Voltage, Volts}}{\text{Resistance, Ohms}}$$

For example, a 100-watt light bulb in your house which is in a 120 volt (AC) circuit has a resistance in the filament of approximately 144 ohms.

$$\text{Current Amps} = \frac{120 \text{ Volts}}{144 \text{ Ohms}} = .83 \text{ Amps}$$

Similarly, a 7.5-watt bulb in a 120-volt circuit results in a current flow of .06 amps. This appears to be a very small amount of current indeed, but let's take a look at the effects of current in the human body.


PUMP
GATE VALVE
WATER FLOW (WATER MOLECULES - LOTS OF THEM)
PUMP SUPPLIES WATER AND PRESSURE
VARIABLE RESISTOR (YOUR BODY)
POWER COMPANY
CURRENT FLOW (ELECTRONS - LOTS OF THEM TOO)
POWER COMPANY SUPPLIES CURRENT AND VOLTAGE

MAXIMUM RESISTANCE = VALVE CLOSED = NO WATER FLOW
MAXIMUM RESISTANCE = OPEN CIRCUIT = NO CURRENT FLOW

MINIMUM RESISTANCE = VALVE OPEN = MAXIMUM WATER FLOW
MINIMUM RESISTANCE = SHORT CIRCUIT = MAXIMUM CURRENT FLOW

	ENERGY (POTENTIAL)	MASS (PARTICLES)	RESTRICTION (TO FLOW)
HYDRAULIC SYSTEM	PRESSURE	WATER (MOLECULES)	VARIABLE VALVE
ELECTRICAL SYSTEM	VOLTAGE	CURRENT (ELECTRONS)	VARIABLE RESISTOR

ELECTRICAL SYSTEM AND HYDRAULIC SYSTEM SIMILARITIES

Fig. 4.22 Water pressure equal to voltage

In this case we will use milliamps which is thousandth (.001) of an amp, so .06 amps becomes 60 milliamps and .83 amps becomes 830 amps.

- 1 milliamp or less, no sensation, not felt.
- More than 5 milliamps, painful shock. (This is 5 thousandths of an amp, .005 amps.)
- More than 10 milliamps, local muscle contractions sufficient to cause "freezing" of the muscles for 2.5 percent of the human population.
- More than 15 milliamps, local muscle contractions sufficient to cause "freezing" to 50 percent of the population.
- More than 30 milliamps, breathing is difficult, can cause unconsciousness.
- 50 to 100 milliamps, possible ventricular fibrillation of the heart (uncontrolled, rapid, beating of the heart muscle).
- Over 200 milliamps, severe burns and muscular contractions, heart more apt to suffer stoppage rather than only fibrillation. (This is only 2 tenths or 200 thousandths of an amp.)
- Over a few amperes, irreparable damage to the body tissue.

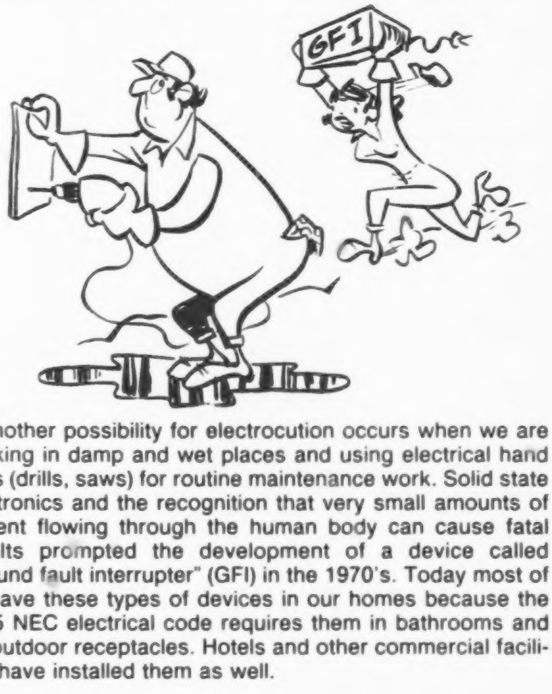
So the current flowing in the 120-volt circuit that lights a 7.5-watt light bulb is enough to cause severe muscular contractions of the heart. Again, the controlling factor that determines the extent of injury is the amount of resistance to the flow of current. Figure 4.23 illustrates some typical body resistances and the subsequent current flow.

- If your head happens to become the load in an electrical circuit, the current flows through the brain from ear to ear. At 100 volts that could allow 1.1 amp of current to flow, which is 1,100 milliamps. Chances for permanent damage or death are very high, since the head offers only 100 ohms of resistance.
- If the current flows through the hand, down through the heart to your foot, this represents a resistance of about 500 ohms, which will allow 220 milliamps of current to flow. Again, potential death through severe muscular contraction of the heart is likely.
- Resistance to current flow is significantly altered if the skin is wet. Dry skin will have a resistance of 100,000 to 600,000 ohms while wet skin will have a resistance of only 1,000 ohms. When dealing with higher voltages such as 220 volts, or 480 volts, or even higher, wet skin allows more current to flow through the body.

ONCE AGAIN, IF YOU ARE NOT QUALIFIED YOU HAVE NO BUSINESS WORKING IN OR AROUND ELECTRICAL SYSTEMS. NOT ONLY ARE YOU CREATING A HAZARD TO YOURSELF, BUT TO YOUR COLLEAGUES AND THE PUBLIC AS WELL. ELECTRICAL MAINTENANCE/INSTALLATION IS CONTROLLED BY RIGID FEDERAL AND STATE REGULATIONS INCLUDING THEM THE NATIONAL ELECTRICAL CODE (NEC) AND LOCAL BUILDING CODES.

If you are qualified and are working on electrical equipment, observe the basic rules listed below.

- Disconnect and lock out all equipment prior to working on it. (See *LOCKOUT PROCEDURE* at the end of this section.)
- Observe common sense procedures which will prevent or reduce the possibility of electrocution through the accidental contact with a live circuit. Use rubber mats, rubber boots, leather gloves or some other form of isolation between you and ground.
- Avoid wearing eye glasses with metal frames, watches, jewelry, or metal belt buckles which can increase the possibility of severe burns and electrocution if they come in contact with electrical circuits.
- Always maintain adequate clearance of body parts with live circuits.
- Professional electricians will always try to work with one hand only when working around live electrical circuits. This, coupled with adequate isolation from the ground through rubber mats and gloves, will minimize the possibility of completing a circuit.
- Electrical codes in many states specify that when working on certain levels of voltage in live circuits you should not be alone. Your partner and colleague should be trained in CPR or other first-responder first aid measures in case of accidental electrocution.
- Wear safety glasses when working on live equipment. Tinted glasses are preferred. Flashing or arcing can damage the eyes through the instantaneous generation and explosion of molten metal and high-intensity arcing from short circuits.
- When resetting tripped circuit breakers, always investigate the cause of the circuit breaker tripping. Although circuit breakers are prone to nuisance-type trips, they are also protective devices indicating possible short circuit or other fault condition downstream. There are cases where even qualified people have neglected to check out the cause of the tripping and have tried to reset the circuit breaker which then exploded. Enclosures should always be closed. For example, shut panel doors when re-energizing a circuit. The doors are a protective device designed to protect you against the explosion of circuit breakers or other electrical components within the enclosure.



Another possibility for electrocution occurs when we are working in damp and wet places and using electrical hand tools (drills, saws) for routine maintenance work. Solid state electronics and the recognition that very small amounts of current flowing through the human body can cause fatal results prompted the development of a device called "ground fault interrupter" (GFI) in the 1970's. Today most of us have these types of devices in our homes because the 1975 NEC electrical code requires them in bathrooms and for outdoor receptacles. Hotels and other commercial facilities have installed them as well.

OHMS LAW

$$\text{CURRENT} = \frac{\text{VOLTAGE}}{\text{RESISTANCE}}$$

OR

$$\text{AMPS} = \frac{\text{VOLTAGE}}{\text{OHMS}}$$

OR

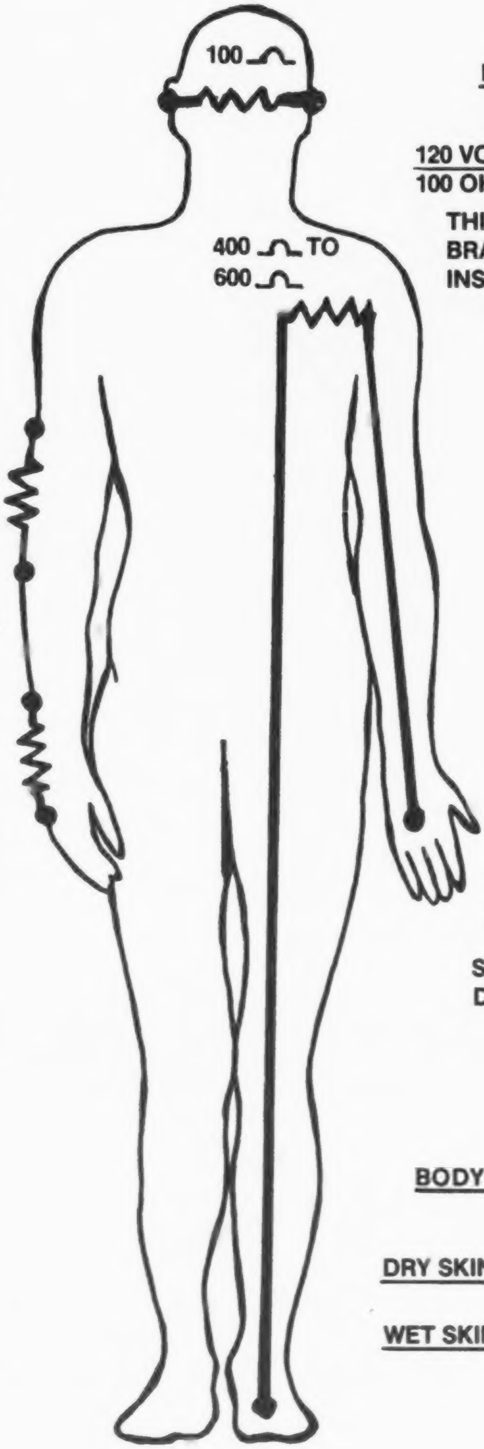
$$A = \frac{V}{O}$$

DRY SKIN EXAMPLE:

$$\frac{\text{120 VOLTS}}{\text{300,000 OHMS}} = \text{0.4 MA}$$

WET SKIN EXAMPLE:

$$\frac{\text{120 VOLTS}}{\text{1000 OHMS}} = \text{120 MA}$$



EAR TO EAR

$$\frac{\text{120 VOLTS}}{\text{100 OHMS}} = \text{1.2 AMPS}$$

THIS WILL FRY YOUR BRAIN AND CAUSE INSTANT DEATH!

HAND TO FOOT

$$\frac{\text{120 VOLTS}}{\text{500 OHMS}} = \text{240 MA}$$

SEVERE BURNS, POSSIBLE DEATH

BODY RESISTANCE RANGES

DRY SKIN - 100,000 - 600,000 OHMS

WET SKIN - 1,000 OHMS

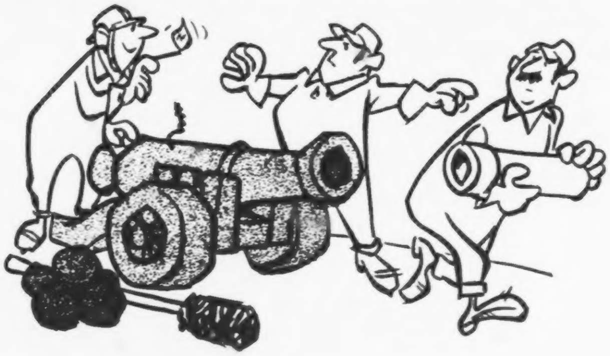
TYPICAL BODY RESISTANCE AND CURRENT FLOW

Fig. 4.23 Typical body resistances and currents
(Permission of General Electric)

A ground fault interrupter provides increased protection for the collection system operator who is almost always working in a damp condition. A portable ground fault interrupter receptacle, available for less than $50, should be used when operating electrical hand tools.

A GFI (Figure 4.24) consists of three essential elements: a sensing element known as a differential transformer; an electronic amplifying section; and a circuit interrupting section. The differential transformer continuously monitors the current in the two conductors of a circuit which are the phase, or "hot line," and the "neutral" line. Under normal conditions these two currents are always equal. If the differential transformer senses a difference between them of as little as 5 milliamps, it assumes the difference is being lost to ground through a fault of some sort. A partially shredded winding in your electrical drill, for example, may cause some of the current to flow into the body of the drill and then into your hand. The electronic amplifying section of the GFI boosts the signal and trips the circuit in 1/40 of a second or less.

Ground fault receptacles should be installed in convenience receptacles where it is wet or damp, and should be carried on your vehicle to use when using portable electrical tools. In addition, a good electrical preventive maintenance program significantly reduces the amount of electrical equipment failure, and therefore exposure to the collection system operator (see Chapter 8, "Lift Stations," and Chapter 9, "Equipment Maintenance" in Volume II).



EXPLOSIVE ATMOSPHERES

The use of electrically powered equipment under certain conditions creates such a serious safety hazard that stringent regulations now govern installations of this kind. The National Electrical Code (NEC) defines different locations and conditions, which it calls Classes and Divisions, and specifies what equipment can be used in each class and how it is to be installed and repaired. The part of the Code that applies to collection system facilities is described below.

Class 1 location (gases). This is defined as an area where flammable gases or vapors may be present in the air in a quantity sufficient to produce explosive or ignitable mixtures.

Classes are further broken down into divisions. Division 1 is an area where concentrations of gases exist continuously, intermittently, or periodically under normal, everyday operating conditions including hazardous materials that might be released during repair or maintenance operations, or in the breakdown or faulty operation of equipment.

The National Electrical Code does not identify specific structures since this would be an impossible task, but it does describe the conditions which might exist. You must take the definition and look at each of your individual facilities to determine whether or not they fall into the category of Class 1, Division 1. If they do, then explosion-proof wiring methods, equipment, and maintenance techniques are required.

Explosives or flammable atmospheres frequently exist in collection system structures. Some examples are the "confined spaces" in gravity sewers, pump station wet wells, or underground vaults where natural gas leaks can accumulate and create explosive atmospheres. (One of the most significant examples of this occurred in the City of Louisville, Kentucky, which suffered $40,000,000 in damage to their sewer system as a result of an explosion creating extensive damage to the Louisville Collection System.)

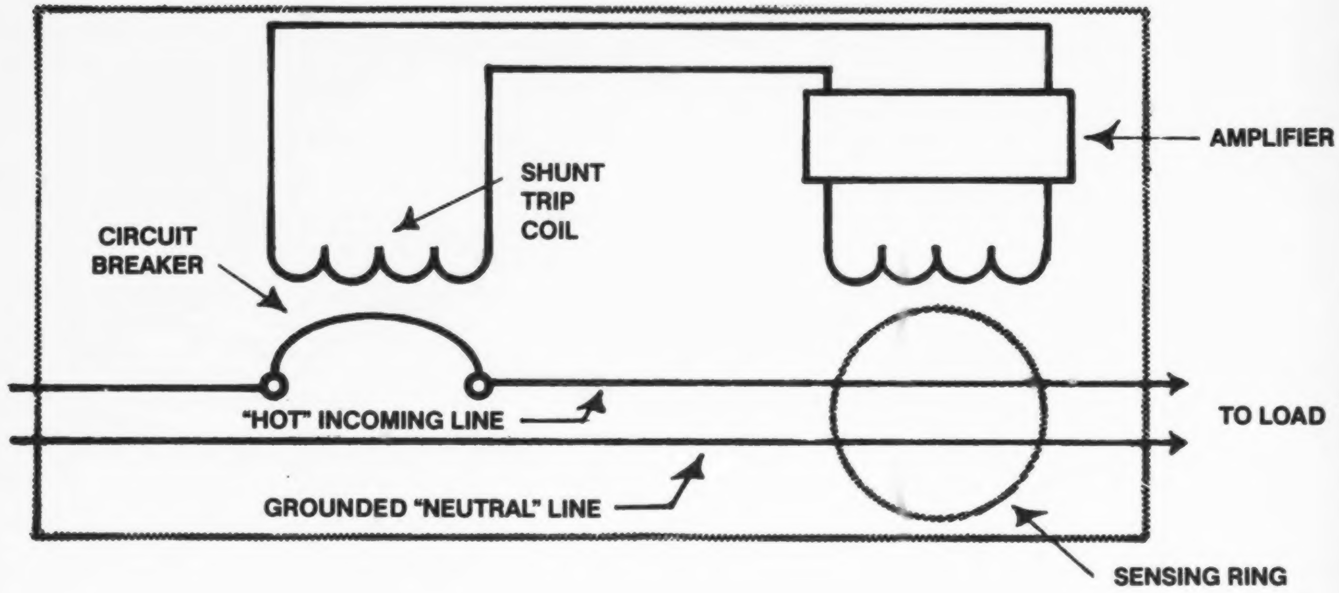
Wet wells frequently have blowers, lights, bar screens or other types of systems that require electricity. The theory of explosion- proof construction is that an explosion can in fact occur within the device; for example, a light fixture. However, because of the construction (cast iron or cast aluminum) the explosion is contained within the fixture. In addition, all surfaces are machined to very close tolerances and are threaded so that as the ignited vapors or gases attempt to work their way out of the fixture, they encounter a long, tortuous route. By the time they do escape to the atmosphere, they are cooled sufficiently to prevent the ignition of the wet well atmosphere.

Electrical equipment and wiring systems designed to operate in Class 1, Division 1 environments are specially designed to eliminate any source of ignition, such as a spark or arcing, that might cause a fire or explosion. Such equipment requires specialized knowledge for installation and maintenance. Under no circumstances should maintenance or repair of these devices, whether it be a motor, light fixture, or conduit system, be attempted by anyone but qualified personnel.

LOCKOUT PROCEDURE

Collection system operators are frequently required to work on mechanical, hydraulic and electrical systems. All of these have the potential of causing serious injury unless some action is taken to prevent the accidental startup of a system while maintenance work is being performed.

There are many forms of energy present in the typical collection system; electrical energy in a pump station, mechanical energy in a surge-relief valve, thermal energy from high temperatures, and energy associated with hydraulic pressure such as static head pressure in a pipeline. Typical equipment systems where these hazards exist are motor control centers, pumps, belts, and spring-loaded devices such as check valves.


SHUNT
TRIP
COIL
CIRCUIT
BREAKER
AMPLIFIER
"HOT" INCOMING LINE
TO LOAD
GROUNDED "NEUTRAL" LINE
SENSING RING

GROUND FAULT INTERRUPTER (GFI) ELEMENTS

THE DIFFERENTIAL TRANSFORMER CONTINUOUSLY MEASURES THE CURRENT FLOW IN THE "HOT" AND "NEUTRAL" LINES. UNDER NORMAL CONDITIONS THE CURRENT IS EQUAL IN EACH LINE. IF THERE IS A DIFFERENCE OF AS LITTLE AS 5 MILLIAMPERES (0.005 AMPS) THE AMPLIFIER ENERGIZES THE SHUNT TRIP COIL WHICH CAUSES THE CIRCUIT BREAKER TO TRIP.

EXAMPLE:

A HAND DRILL HAS A DEFECTIVE MOTOR WINDING ALLOWING A PORTION OF THE CURRENT TO FLOW TO THE METAL CASE AND THUS THROUGH YOUR BODY CAUSING A SHOCK AND POSSIBLE ELECTROCUTION.

ALWAYS USE A GFI WHEN USING ELECTRICAL EQUIPMENT OUTDOORS AND IN DAMP, WET LOCATIONS. ALWAYS MAKE SURE YOUR ELECTRICAL TOOLS ARE IN GOOD SHAPE.

Fig. 4.24 Ground fault interrupter

It is imperative for the collection system operator to take appropriate precautions to prevent the accidental discharge of energy from these systems because it could cause serious injury or death. Before performing any maintenance, be sure you thoroughly understand the systems you are working on and the precautions you need to take.

The following is a suggested lockout procedure you can use when performing maintenance where potential hazards exist.

Whenever it is necessary to work on a piece of equipment or machinery, the following procedure shall be adhered to:

1. The main power source shall be locked out, in the off position, with a multiple lockout device and padlock. (*NOTE:* the pulling of fuses shall not be considered a substitute for locking out.)
2. All pneumatic, hydraulic and other fluid lines shall be bled, drained, purged or blanked off to eliminate pressure and/or contents, mechanisms under spring tension or compression shall be blocked, clamped, or chained in position. Blocks may also be needed on some machinery or equipment to prevent gravitational movement.
3. Never place locks where the disconnect can be bypassed at other locations.
4. Multiple lockout devices shall be used in all cases. Each employee who is engaged in working on machinery or equipment shall affix a lock to the multiple lockout device. Each lock shall be individually keyed to prevent unauthorized removal from the lockout device. The employee using the padlock is the only person authorized to remove it.
5. A tagging system shall be used, which will advise other employees of the work being performed.
6. CAUTION: It is mandatory that the disconnect or valve be tried to make sure it cannot be moved to "on." In addition, the machine controls themselves shall be tried to make certain that the controls are "off."
7. This procedure shall be followed at the start of each shift or workday.
8. The immediate supervisor shall check to determine that all requirements of this procedure have been complied with and shall give the personnel involved the clearance to proceed with the required task.
9. In case of emergency, supervisory personnel may authorize breaking the lock after all precautions have been taken. An attempt shall be made to contact the person who initially locked out the equipment (see step 5). A check shall be made to assure that all personnel, tools and other items will not be exposed to harm or injury before the lock is broken. The employee signing the tag shall be notified of the cutting of the lock at the start of the employee's next scheduled workday.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 171.

4.8A What is the first rule that applies to electrical systems?

4.8B What is the "closed loop" similarity between hydraulic and electrical systems?

4.8C When working with electrical circuits, how can you provide isolation between you and the ground?

4.9 WORKING NEAR NOISE

Operators must be protected from the effects of exposure to noise when the sound levels exceed the limits listed in Table 4.1. Use engineering methods of controlling noise whenever possible. If noise levels cannot be controlled within acceptable limits, operators must be provided with and must use approved ear plugs, muffs, and/or personal protective equipment.

TABLE 4.1 HEARING PROTECTION[a]

1. When employees are exposed to loud or extended noise, ear plugs and/or protective devices shall be provided and employees shall wear them accordingly.
2. Protection against the effects of noise exposure shall be provided when sound levels exceed those shown in rule number six. These measurements shall be made on the A-scale of a standard sound level meter at a slow response.
3. When employees are subjected to sound levels exceeding those listed in rule number six, feasible administrative and/or engineering controls shall be utilized. If such controls fail to reduce employees' exposure to within the permissible noise levels listed in this table, personal protective equipment shall be provided and used.
4. Plain cotton shall not be considered acceptable as an ear plug.
5. Machinery creating excessive noise shall be equipped with mufflers.
6. Employees shall not be exposed to noise which exceeds the levels listed below for a time period not to exceed those listed below.

DURATION: HOURS PER DAY		SOUND LEVEL: dBA SLOW RESPONSE
8	....	90
6	....	92
4	....	95
3	....	97
2	....	100
1½	....	102
1	....	105
½	(thirty minutes)	110
¼	(one-fourth-hour or less)	115

---

[a] *Occupational Safety and Health Standards, Subpart G, Paragraph 1910,94, Noise Exposure.*

4.10 FIRE FIGHTING

Everyone must know what to do in case of a fire. If proper action is taken quickly, fires are less likely to cause damage and injury. In order to put a fire out promptly, the proper type of fire extinguisher must be used.

Fires are classified into four categories depending on the material causing the fire.

CLASS	MATERIAL
A	Ordinary combustibles such as wood, paper, cloth or trash.
B	Flammable liquids such as gas, oil, grease or paint.
C	Live electricity such as a short circuit.
D	Metals such as magnesium or sodium.

Be sure to apply the correct method when attempting to extinguish a fire as summarized below:

CLASS	METHOD OF EXTINGUISHING
A	Water
B	Foam, carbon dioxide, dry chemicals
C	Carbon dioxide, dry chemicals
D	Carbon dioxide

Use water *ONLY* on Class A fires. Never direct a stream of water on flammable liquids, electrical fires or metals. Most fire extinguishers are fairly effective on ordinary combustibles. Flammable liquid fires are fought with a loaded stream vaporizing liquid, foam, carbon dioxide (CO_2) and dry chemical extinguishers. Use only carbon dioxide and dry chemical extinguishers on electrical fires. You could be electrocuted if you tried to spray water on an electrical fire. If possible, turn off power to an electrical fire. Carbon dioxide can be used to put out a metal fire. Never use carbon tetrachloride because the fumes are extremely toxic and, when used on hot electrical fires, phosgene (a toxic war gas) can be produced.

EXTINGUISHER
FIRE

Mount fire extinguishers in conspicuous locations and install signs or lights nearby to assist people in finding them. Everyone should know how fires are classified and the appropriate extinguisher for each class. Post the phone number of the local fire department in an obvious location by every phone.

Inspect all fire fighting equipment and extinguishers on a regular basis, such as every 3 or 6 months, and after each use. Always refill extinguishers promptly after use.

Clearly mark all exits from pump stations and other buildings. Post conspicuous signs identifying flammable storage areas and signs prohibiting smoking where smoking is not allowed.

The best way to fight fires is to prevent them from occurring. Fires can be prevented by careful extinguishing of cigarettes and good housekeeping of combustibles, flammable liquids and electrical equipment and circuits.[5]

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 171.

4.9A What should collection system operators do if noise levels cannot be controlled within acceptable limits?

4.10A What different types of materials can cause different types or classes of fires?

4.10B How can each class or type of fire be extinguished?

4.10C How often should fire fighting equipment and extinguishers be inspected?

4.11 HAZARD COMMUNICATION (WORKER RIGHT-TO-KNOW LAWS)

In the past few years, there has been an increase emphasis nationally on hazardous materials and wastes. Much of this attention has focused on hazardous and toxic waste dumps, and the efforts to clean them up after the long-term effects on human health were recognized. Each year thousands of new chemical compounds are produced for industrial, commercial, and household use. Frequently, the long-term effects of these chemicals are unknown. As a result, federal and state laws have been enacted to control all aspects of hazardous materials handling and use. These laws can and should affect the collection system operator, since we are exposed to a variety of hazardous materials. Exposure can occur from one or more of the following:

---

[5] *Slide tape series on the "Use of Fire Extinguishers" (#SL-47, price $115.00) and "Use of Self-Contained Breathing Equipment" (#VC-26BT-VC-26CT-VC-26VH, price $265.00) are available from National Fire Prevention Association 10970, Publication Sales Department, Batterymarch Park, Quincy, MA 02269.*

1. Use of the collection system as an intentional or accidental disposal method for hazardous materials; for example,
    a. Industrial solvents,
    b. Acids,
    c. Flammable/explosive compounds,
    d. Caustics, and
    e. Toxics.
2. Chemicals and chemical compounds that we use every day for maintenance in the collection system; for example,
    a. Solvents,
    b. Degreasers,
    c. Acids,
    d. Chlorine, and
    e. Industrial cleaners.

These laws are more commonly known as Worker Right-To-Know (R-T-K) laws. Every state s covered by one or more laws regarding Worker Right-To-Know. The Federal Occupational Safety and Health Administration (OSHA) Standard 29FR1910.1200 - Hazard Communication forms the basis of most laws. Although the current federal standards are directed at the manufacturing sector, future legislation can be expected to modify the federal standard to include all industries including the public sector and, therefore, collection systems.

In many cases, the individual states have the authority under the OSHA standard to develop their own state Worker Right-To-Know laws and, as of this edition (1987), 35 states have adopted their own laws. Unfortunately, state laws vary significantly from state to state. The state laws that have been passed are at least as stringent as the federal standard, and in most cases, are even more stringent and already apply to collection system operators.

State laws are also under continuous revision and, because a strong emphasis is being placed on hazardous materials and worker exposure, state laws can be expected to be amended in the near future to apply to virtually everybody in the workplace.

The purpose of this section is to familiarize you with general requirements of Worker RTK elements, so that you are better prepared as a collection system operator to minimize risk to yourself and your colleagues from hazardous materials, and to comply with state and federal laws as well. Because of the wide diversity of existing laws, these guidelines may or may not meet your state's requirements. This section will give you an overview of the basic elements of a hazard communication program which can be particularly useful if your agency currently does not have one. An extremely effective program can be developed inhouse through your safety program and committee (see Chapter 10). By cutting through the bureaucratic/legal language and applying some common sense to what the law is trying to accomplish (protection of the worker in the workplace from hazardous materials) an effective program can be developed.

Basically, the different elements of the program are as follows (see Table 4.2):

1. Determine Hazardous Materials

While there are thousands and thousands of chemical compounds which would fall under this definition in a practical sense, collection system operators should be concerned, first of all, with the materials they use in their everyday maintenance activities; and also with materials that can be introduced to the collection system through intentional or accidental spills. Information on materials that could be introduced into the collection system can be obtained from industrial pretreatment inspectors.

In particular, you should be familiar with the industries in your area and be aware of the materials they routinely discharge into the collection system as well as the types of hazardous materials they might accidentally discharge. In some cases, special precautions may have to be taken. For example, when performing routine maintenance with a high-velocity cleaner (jet machine) in a section of line, you may wish to draw up an agreement with an industrial discharger upstream to halt discharges on the day the sewer maintenance is being performed. Hazardous materials can be broken down into general categories as follows:

1. Corrosives,
2. Toxics,
3. Flammables and explosives,
4. Asphyxiants,
5. Harmful physical agents, and
6. Infectious agents.

A complete inventory of materials in use will produce a list similar to the following:

1. Corrosives
    a. Sodium hydroxide
    b. Calcium oxide (lime)
    c. Hydrochloric acid
    d. Ferric chloride
2. Toxics
    a. Hydrogen sulfide
    b. Chlorine
    c. Carbon monoxide
3. Flammables and Explosives
    a. Methane
    b. Acetylene
    c. Gasoline
    d. Solvents
4. Asphyxiants
    a. Carbon Dioxide
    b. Nitrogen
    c. Halon 1301 (used in computer system fire suppression systems)
5. Harmful Physical Agents
    a. Noise
    b. Temperature
    c. Radiation
6. Infectious Agents

2. Obtain Chemical Information and Hazardous Conditions

Once the inventory is complete, the next step is to obtain specific information on each of the chemicals and hazardous conditions. This information is generally incorporated into a standard format form called the "Material Safety Data Sheet" (MSDS). Table 4.3 is the Material Safety Data Sheet (OSHA 174, September, 1985) produced by the U.S. Department of Labor, Occupational Safety and Health Administration. This information is commonly available from hazardous material manufacturers. Many agencies request an MSDS sheet when the purchase order is generated and will refuse to

TABLE 4.2 ELEMENTS OF A HAZARD COMMUNICATION PROGRAM

I. *WRITTEN HAZARD COMMUNICATION PROGRAM*

  A. Hazard Determination (Chemical manufacturers and importers only)

    1. Person(s) responsible for evaluating the chemical(s)
    2. List of sources to be consulted
    3. Criteria to be used to evaluate studies
    4. A plan for reviewing information to update MSDS if new and significant information is found

  B. Labels and Other Forms of Warning

    1. Person(s) responsible for labeling in-plant containers; if used
    2. Person(s) responsible for labeling shipped containers
    3. Description of labeling system
    4. Description of written alternatives to labeling of in-plant containers; if used
    5. Procedure to review and update label information

  C. Material Safety Data Sheets

    1. Person(s) responsible for obtaining/maintaining the MSDS
    2. Description of how the MSDSs will be made available to employees
    3. Procedure to follow when the MSDS is not received at time of first shipment
    4. Procedure to review and update MSDS information
    5. Description of alternatives to actual data sheets in the workplace; if used

  D. Training

    1. Person(s) responsible for conducting training
    2. Format of the program to be used
    3. Elements of the training program

      a. Requirements of the OSHA standard
      b. Operations, where hazardous chemicals are present in routine tasks, non-routine tasks, and foreseeable emergencies
      c. Location and availability of

        i. Written hazard communication program
        ii. List of hazardous chemicals
        iii. MSDS

      d. Methods and observations that may be used to detect the presence or release of hazardous chemicals in the work area
      e. Physical and health hazards of chemicals in the work area
      f. Measures employees can take to protect themselves from hazards
      g. Details for the Hazard Communication Program developed

    4. Procedure to train new employees, as well as current employees when a new chemical hazard is introduced into the workplace

  E. List of hazardous chemicals

  F. Procedure to inform employees of the hazards of chemicals in unlabeled pipes

  G. Procedure to inform on-site contractors

II. *LABELS AND OTHER FORMS OF WARNING*

  A. Labels or other markings on each container of hazardous chemicals

    1. Process vessels
    2. Storage tanks
    3. Compressed gas cylinders
    4. Product containers
    5. Tank truck/tank car labels

III. *MATERIAL SAFETY DATA SHEETS*

  A. MSDS' developed or obtained for all hazardous chemicals

  B. Employees have access on each shift

  C. MSDSs completed appropriately

  D. When no MSDS is available, the documentation requesting an MSDS from supplier is maintained

TABLE 4.2 ELEMENTS OF A HAZARD COMMUNICATION PROGRAM (CONTINUED)

IV. *TRAINING*

  A. Employee training files

  B. Employee questioning:

    1. Awareness of the HCS and its requirements
    2. Have they received training
    3. Ability to locate the MSDSs
    4. General familiarity with the hazardous properties of the chemicals in their workplace

accept delivery of the shipment if the MSDS sheet is not included.

The purpose of the MSDS sheet is to have a readily available reference document that includes complete information on common names, safe exposure level, effects of exposure, symptoms of exposure, flammability rating, type of first aid procedures, and other information about each hazardous substance.

Operators should be trained to read and understand the MSDS forms. The forms themselves should be stored in a convenient location where they are readily available for reference.

3. Properly Label Hazards

Once the physical, chemical, and health hazards have been identified and listed, a labeling and training program must be implemented. To meet labeling requirements on hazardous materials, specialized labeling is available from a number of sources, including commercial label manufacturers.

LABELING REQUIREMENTS:

The label must indicate the following:

1. All hazards to which the employees are exposed,
2. Symptoms of exposure,
3. Appropriate emergency treatment,
4. Proper conditions for safe use, and
5. Precautions against exposure.

Specifically, containers of hazardous substances must be labeled with an approved method of warning. There are a number of acceptable labeling systems available, including private labeling systems such as illustrated in Figure 4.25 produced by J. T. Baker Chemical Company. The second illustration is produced by a commercial label maker (Figure 4.26) and the third in Figure 4.27 is one designed by the National Fire Protection Association (NFPA).

These are standardized formats that use a combination of pictographs, a numbering system, and colors to indicate various levels of conditions. In some cases, the MSDS sheet can be incorporated into the labeling requirements by locating the appropriate MSDS sheet in close proximity to drums or storage areas. The labeling requirements offer the collection system operator virtually instant recognition of the hazards in dealing with specific substances, protective equipment required, and other information.[6]

4. Train Operators

The last element in the Hazard Communication Worker Right-To-Know Program is training and making information available to the collection system operator. Once the material and physical agents are identified in the collection system environment which the operator may be exposed to, they are categorized by group; for example, corrosives, toxics, flammables and explosives, asphyxiants, harmful physical agents, and infectious agents.

A common sense approach eliminates the confusing issue of which of the thousands of substances operators should be trained for, and concentrates on those that they will be exposed to or use in everyday maintenance routines. Obviously, the protection from hazardous materials is tied in with the Confined Space policy, since average domestic wastewater found in the collection system does not contain sufficient concentrations of hazardous materials to address each of the compounds which may be found. The use of ventilating equipment, atmospheric testing instrumentation and the other precautions defined in the Confined Space procedure assist in protecting the collection system operator from hazardous materials.

Industrial dischargers can and do discharge significant concentrations of hazardous materials, either intentionally or unintentionally. A collection system operator should be familiar with each industry that discharges to the collection system, since they may require special precautions to minimize exposure to hazardous materials.

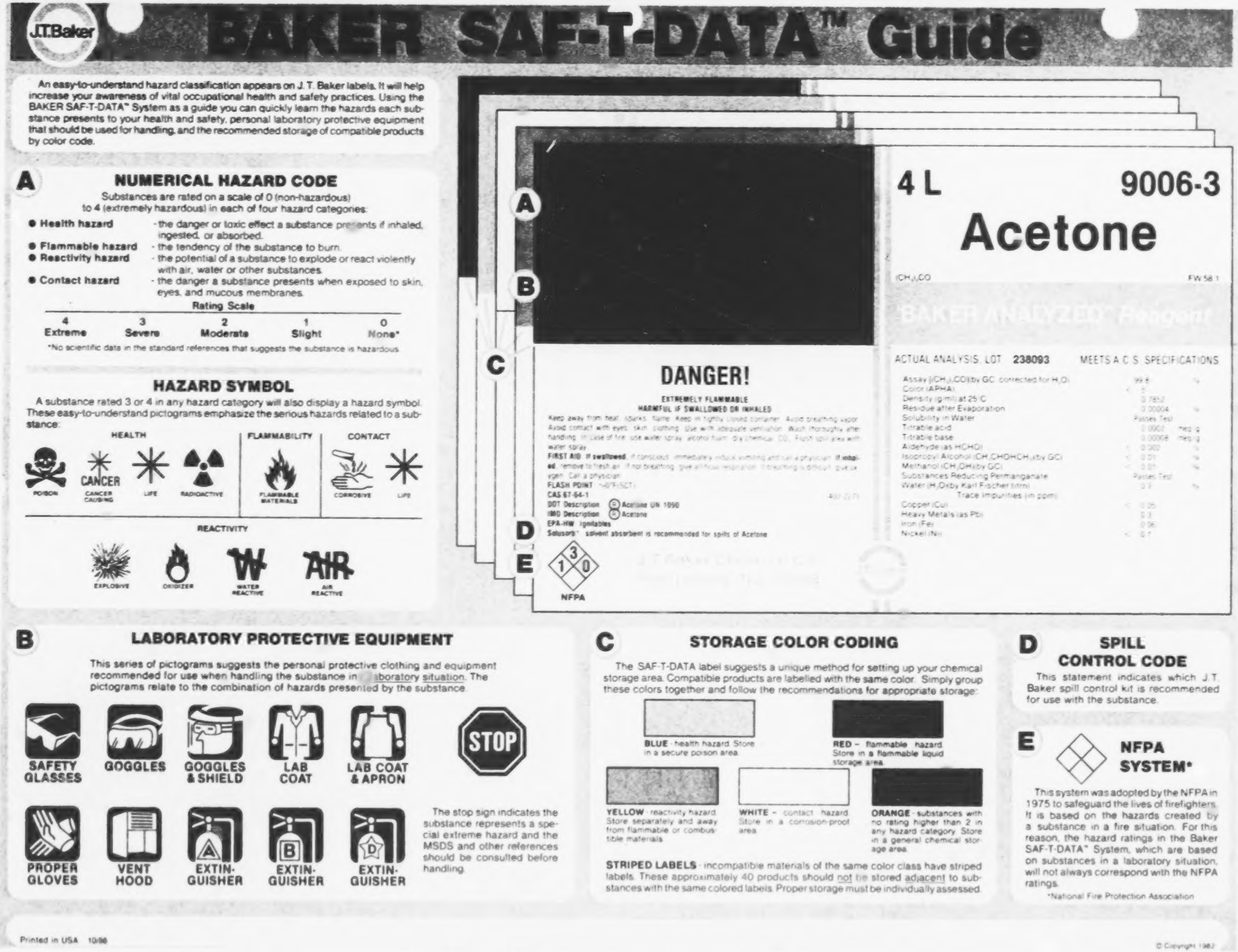
The last element is a formal training program provided by qualified personnel designed to accomplish the following:

1. Make employees aware of the hazard communication standard and what its requirements are;
2. Familiarize employees with operations and hazardous substances that are present in their routine and non-routine maintenance tasks and how to deal with emergency situations regarding those materials and conditions;
3. Introduce MSDS sheet and have an MSDS file readily available for reference;
4. Train in the utilization of the labeling format; and
5. Document what training has been performed.

The hazard communication standard and the individual state requirements are obviously a very complex set of regulations. Remember, however, the ultimate goal of these regulations and other collection system procedures is to

---

[6] *The United States and Europe are working on an internationally acceptable labeling system, which ultimately could lead to standardized labeling for 575,000 chemical mixtures.*



BAKER SAF-T-DATA™ Guide

J.T.Baker

An easy-to-understand hazard classification appears on J. T. Baker labels. It will help increase your awareness of vital occupational health and safety practices. Using the BAKER SAF-T-DATA™ System as a guide you can quickly learn the hazards each substance presents to your health and safety, personal laboratory protective equipment that should be used for handling, and the recommended storage of compatible products by color code.

A NUMERICAL HAZARD CODE

Substances are rated on a scale of 0 (non-hazardous) to 4 (extremely hazardous) in each of four hazard categories:

- **Health hazard** - the danger or toxic effect a substance presents if inhaled, ingested, or absorbed.
- **Flammable hazard** - the tendency of the substance to burn.
- **Reactivity hazard** - the potential of a substance to explode or react violently with air, water or other substances.
- **Contact hazard** - the danger a substance presents when exposed to skin, eyes, and mucous membranes.

Rating Scale

4	3	2	1	0
Extreme	**Severe**	**Moderate**	**Slight**	**None***

*No scientific data in the standard references that suggests the substance is hazardous.

HAZARD SYMBOL

A substance rated 3 or 4 in any hazard category will also display a hazard symbol. These easy-to-understand pictograms emphasize the serious hazards related to a substance:

4 L **9006-3**

Acetone

$(CH_3)_2CO$ FW 58.1

BAKER ANALYZED® Reagent

DANGER!

EXTREMELY FLAMMABLE
HARMFUL IF SWALLOWED OR INHALED

Keep away from heat, sparks, flame. Keep in tightly closed container. Avoid breathing vapor. Avoid contact with eyes, skin, clothing. Use with adequate ventilation. Wash thoroughly after handling. In case of fire, use water spray, alcohol foam, dry chemical, CO_2. Flush spill area with water spray.

FIRST AID: If swallowed, if conscious, immediately induce vomiting and call a physician. **If inhaled,** remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Call a physician.

FLASH POINT [illegible]

CAS 67-64-1 [illegible]

DOT Description Ⓡ Acetone UN 1090

IMO Description Ⓡ Acetone

EPA-HW Ignitables

Solusorb™ solvent absorbent is recommended for spills of Acetone

ACTUAL ANALYSIS, LOT **238093** MEETS A.C.S. SPECIFICATIONS

Assay $((CH_3)_2CO)$ by GC, corrected for H_2O		99.8	%
Color (APHA)	<	5	
Density (g/ml) at 25°C		0.7852	
Residue after Evaporation		0.00004	%
Solubility in Water		Passes Test	
Titrable acid		0.0002	meq/g
Titrable base		0.00008	meq/g
Aldehyde (as HCHO)	<	0.002	%
Isopropyl Alcohol $(CH_3CHOHCH_3)$ by GC	<	0.01	%
Methanol (CH_3OH) by GC	<	0.01	%
Substances Reducing Permanganate		Passes Test	
Water (H_2O) by Karl Fischer titrn.		0.2	%
Trace Impurities (in ppm)			
Copper (Cu)	<	0.05	
Heavy Metals (as Pb)		0.3	
Iron (Fe)		0.06	
Nickel (Ni)	<	0.1	

B LABORATORY PROTECTIVE EQUIPMENT

This series of pictograms suggests the personal protective clothing and equipment recommended for use when handling the substance in a laboratory situation. The pictograms relate to the combination of hazards presented by the substance.

The stop sign indicates the substance represents a special extreme hazard and the MSDS and other references should be consulted before handling.

C STORAGE COLOR CODING

The SAF-T-DATA label suggests a unique method for setting up your chemical storage area. Compatible products are labelled with the same color. Simply group these colors together and follow the recommendations for appropriate storage:

BLUE - health hazard. Store in a secure poison area.

RED - flammable hazard. Store in a flammable liquid storage area.

YELLOW - reactivity hazard. Store separately and away from flammable or combustible materials.

WHITE - contact hazard. Store in a corrosion-proof area.

ORANGE - substances with no rating higher than 2 in any hazard category. Store in a general chemical storage area.

STRIPED LABELS - incompatible materials of the same color class have striped labels. These approximately 40 products should not be stored adjacent to substances with the same colored labels. Proper storage must be individually assessed.

D SPILL CONTROL CODE

This statement indicates which J.T. Baker spill control kit is recommended for use with the substance.

E NFPA SYSTEM*

This system was adopted by the NFPA in 1975 to safeguard the lives of firefighters. It is based on the hazards created by a substance in a fire situation. For this reason, the hazard ratings in the Baker SAF-T-DATA™ System, which are based on substances in a laboratory situation, will not always correspond with the NFPA ratings.

*National Fire Protection Association

Printed in USA 10/86

© Copyright 1982

Fig. 4.25 J. T. Baker hazardous substance labeling system
(Permission of J. T. Baker Chemical Company)

178

BEST COPY AVAILABLE

179

TABLE 4.3 MATERIAL SAFETY DATA SHEET

Material Safety Data Sheet May be used to comply with OSHA's Hazard Communication Standard. 29 CFR 1910.1200. Standard must be consulted for specific requirements.	**U.S. Department of Labor** Occupational Safety and Health Administration (Non-Mandatory Form) Form Approved OMB No. 1218-0072
IDENTITY *(As Used on Label and List)*	*Note: Blank spaces are not permitted. If any item is not applicable, or no information is available, the space must be marked to indicate that.*

Section I

Manufacturer's Name	Emergency Telephone Number
Address *(Number, Street, City, State, and ZIP Code)*	Telephone Number for Information
	Date Prepared
	Signature of Preparer *(optional)*

Section II — Hazardous Ingredients/Identity Information

Hazardous Components (Specific Chemical Identity; Common Name(s))	OSHA PEL	ACGIH TLV	Other Limits Recommended	% *(optional)*

Section III — Physical/Chemical Characteristics

Boiling Point		Specific Gravity (H_2O = 1)	
Vapor Pressure (mm Hg.)		Melting Point	
Vapor Density (AIR = 1)		Evaporation Rate (Butyl Acetate = 1)	
Solubility in Water			
Appearance and Odor			

Section IV — Fire and Explosion Hazard Data

Flash Point (Method Used)	Flammable Limits	LEL	UEL
Extinguishing Media			
Special Fire Fighting Procedures			
Unusual Fire and Explosion Hazards			

(Reproduce locally)

OSHA 174, Sept. 1985

TABLE 4.3 MATERIAL SAFETY DATA SHEET (CONTINUED)

Section V — Reactivity Data

Stability	Unstable		Conditions to Avoid
	Stable		

Incompatibility (*Materials to Avoid*)

Hazardous Decomposition or Byproducts

Hazardous Polymerization	May Occur		Conditions to Avoid
	Will Not Occur		

Section VI — Health Hazard Data

Route(s) of Entry:	Inhalation?	Skin?	Ingestion?

Health Hazards (*Acute and Chronic*)

Carcinogenicity:	NTP?	IARC Monographs?	OSHA Regulated?

Signs and Symptoms of Exposure

Medical Conditions
Generally Aggravated by Exposure

Emergency and First Aid Procedures

Section VII — Precautions for Safe Handling and Use

Steps to Be Taken in Case Material Is Released or Spilled

Waste Disposal Method

Precautions to Be Taken in Handling and Storing

Other Precautions

Section VIII — Control Measures

Respiratory Protection (*Specify Type*)

Ventilation	Local Exhaust	Special
	Mechanical (*General*)	Other

Protective Gloves	Eye Protection

Other Protective Clothing or Equipment

Work/Hygienic Practices

• USGPO 1986-491-529/45775

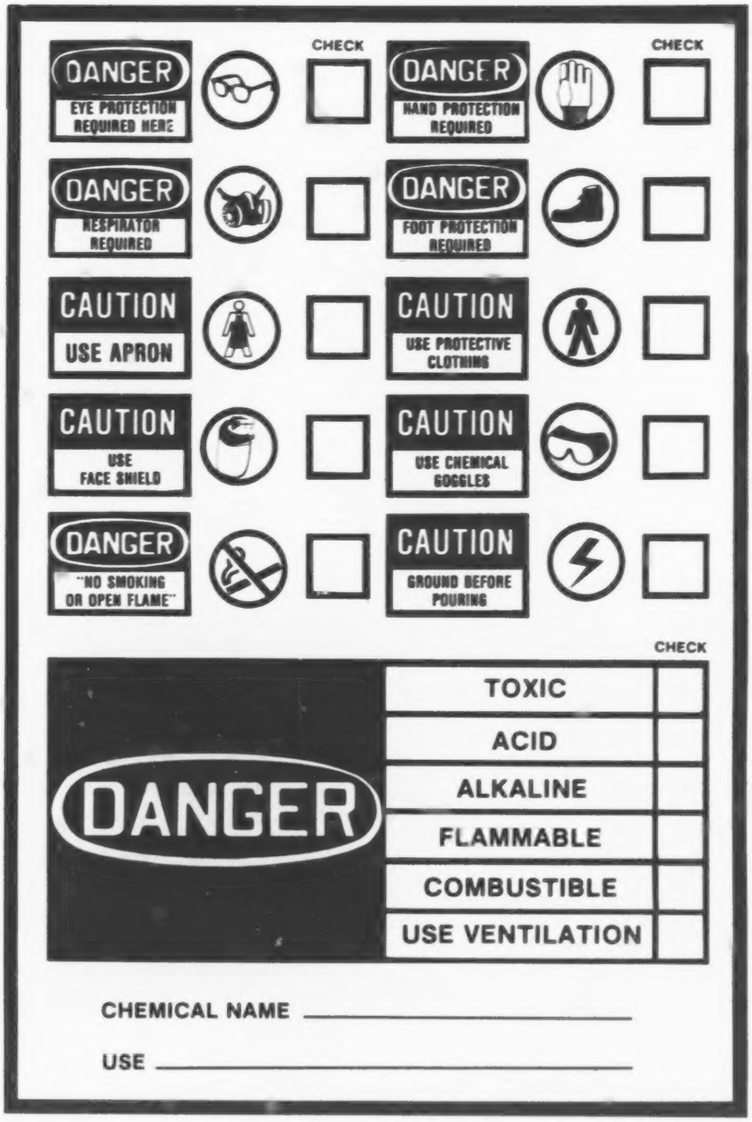

CHECK
DANGER
EYE PROTECTION REQUIRED HERE
DANGER
HAND PROTECTION REQUIRED
CHECK
DANGER
RESPIRATOR REQUIRED
DANGER
FOOT PROTECTION REQUIRED
CAUTION
USE APRON
CAUTION
USE PROTECTIVE CLOTHING
CAUTION
USE FACE SHIELD
CAUTION
USE CHEMICAL GOGGLES
DANGER
"NO SMOKING OR OPEN FLAME"
CAUTION
GROUND BEFORE POURING
CHECK
DANGER
TOXIC
ACID
ALKALINE
FLAMMABLE
COMBUSTIBLE
USE VENTILATION
CHEMICAL NAME
USE

Fig. 4.26 Commercial warning labels
(Permission of the SIGNMARK Division, W. H. Brady Co.)

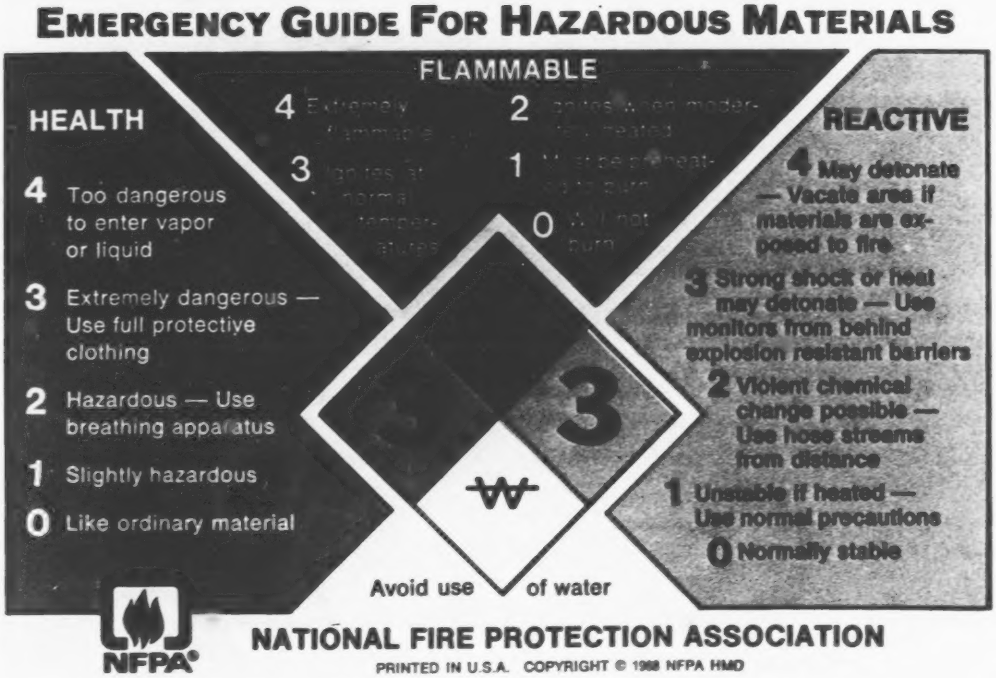

EMERGENCY GUIDE FOR HAZARDOUS MATERIALS
FLAMMABLE
4 Extremely flammable
3 Ignites at normal temperatures
2 Ignites when moderately heated
1 Must be preheated to burn
0 Will not burn
HEALTH
4 Too dangerous to enter vapor or liquid
3 Extremely dangerous — Use full protective clothing
2 Hazardous — Use breathing apparatus
1 Slightly hazardous
0 Like ordinary material
REACTIVE
4 May detonate — Vacate area if materials are exposed to fire
3 Strong shock or heat may detonate — Use monitors from behind explosion resistant barriers
2 Violent chemical change possible — Use hose streams from distance
1 Unstable if heated — Use normal precautions
0 Normally stable
3
₩
Avoid use of water
NFPA
NATIONAL FIRE PROTECTION ASSOCIATION
PRINTED IN U.S.A. COPYRIGHT © 1968 NFPA HMD

Fig. 4.27 NFPA Hazard Warning Label
(Permission of National Fire Protection Association)

provide additional operator protection. These standards and regulations, once the intent is understood, are relatively easy to implement and can certainly be accomplished in-house by the safety structure as suggested in Chapter 11.

When all is said and done, common sense, knowledge, awareness and commitment are the keys to complying with the hazardous material and the Worker Right-To-Know regulations.

It is anticipated that OSHA's proposal to revise the existing standard will be completed in March of 1987. The existing standard covers fewer than one third of all employees, which is 14,000,000 workers in 300,000 work sites. The same activity can be expected at the state level. Depending on what state you are in, your agency could be in violation of federal and state regulations if it does not currently have a Worker Right-To-Know policy. As more states which are covered by the federal standard revise their laws, it is anticipated that in the near future all employees will be covered by Worker Right-To-Know laws.

4.12 ADDITIONAL READING

1. *SAFETY AND HEALTH IN WASTEWATER SYSTEMS,* Manual of Practice No. 1, Water Pollution Control Federation, 601 Wythe Street, Alexandria, Virginia 22314-1994. Price, $19.00 to members; $25.00 to others. Indicate your member association when ordering.
2. Chapter 3, "Wastewater Collection Systems," Section 3.70, "Evacuation and Shoring."
3. Chapter 11, "Safety/Survival Programs for Collection System Operators," in Volume II of this manual.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 172.

4.11A List the four basic elements of a hazard communication program.

4.11B List the general categories of hazardous materials.

4.11C What is the purpose of the MSDS sheet?

4.11D What information must be on the label of a hazardous material?

DISCUSSION AND REVIEW QUESTIONS

Chapter 4 SAFE PROCEDURES

Please write the answers to these questions in your notebook. The purpose of these questions is to indicate to you how well you understand the material in the chapter.

1. What types of hazardous tasks are performed by collection system operators?
2. Which items on a vehicle and towed equipment should be inspected before leaving the yard?
3. How could you obtain information on defensive driving programs in your area?
4. What is the definition of the phrase "dangerous air contamination?"
5. How can explosive or flammable atmospheres develop in a collection system?
6. How can toxic acids, bases and other hazardous liquid or solid chemicals enter wastewater collection systems?
7. What types of equipment and situations increase collection system operators' exposure to electrical hazards?
8. What are the basic rules for qualified persons working with electricity?
9. How can collection system operators protect their hearing from loud noises?
10. How would you extinguish a fire?
11. How can collection system operators be exposed to hazardous materials?
12. Why should collection system operators be familiar with worker "Right-To-Know" laws?

SUGGESTED ANSWERS

Chapter 4 SAFE PROCEDURES

Answers to questions on page 116.

4.0A Different types of vehicles a collection system operator may be expected to drive include tankers, rodding machines, boom trucks, standby power generators, foaming trailers, TV/grout rigs, compressors, trailer mounted/engine driven pumps, and construction equipment.

4.1A Collection system operators must follow established procedures because of the serious consequences that could result due to the nature of the job and the increased risk of injury and/or fatality to the operator and co-workers.

4.1B Before leaving the maintenance yard or shop, discuss work assignments, determine equipment needed, inspect equipment that will be used, and inspect vehicles and towed equipment.

4.1C Before taking an atmospheric testing device out to a job site it should be calibrated and working properly.

4.2A Defensive driving is not only a mature attitude toward driving, but a strategy as well. You must always be on the alert for the large number of new drivers, inattentive or sleeping drivers, people driving under the influence of alcohol and/or drugs, and those drivers who are just plain incompetent. In addition, weather, construction, and the type of equipment you are driving can also present hazards.

Answers to questions on page 124.

4.3A Any time traffic may be affected, appropriate authorities must be notified which could be state, county or local. Frequently a permit must be issued by the authority which has jurisdiction before traffic can be diverted or disrupted.

4.3B Traffic can be warned of your presence in a street by *"MEN WORKING"* and *"CAUTION, CONSTRUCTION WORK"* signs. Signs with flags or flashers and vehicles with rotating flashing lights are used to warn other motorists. Vehicle mounted traffic guides are also helpful. Use flagmen to alert drivers and to direct traffic around the work site.

4.3C Once motorists have been warned, they must be safely routed around the job site. Traffic routing includes the use of flagmen and directional signs. Barricades and traffic cones properly placed can effectively channel traffic from one lane to another around the job site. Traffic officers can be used to direct traffic if streets are narrow and/or if there is considerable traffic or congestion.

4.3D The five different areas of traffic control are (1) advance warning, (2) transition, (3) buffer, (4) work, and (5) termination areas.

Answers to questions on page 133.

4.4A The major categories of hazards you may encounter when entering a manhole include atmospheric, physical injury, infection and disease, insects and biting critters, toxic exposure, and drowning.

4.4B A confined space is any space where both of the following conditions exist at the same time:
  A. Existing ventilation is insufficient to remove dangerous air contamination and/or oxygen deficiency which may exist or develop, and
  B. Ready access or egress (getting out) for the removal of a suddenly disabled employee (operator) is difficult due to the location and/or size of the opening(s).

4.4C The top portion of the atmosphere in a manhole can test "safe" when the bottom portion is dangerous because dangerous gases that are heavier than air can accumulate in the bottom of a manhole.

4.4D Atmospheric hazards encountered in manholes include:
  1. Explosive or flammable atmospheres
     a. Methane gas
     b. Propane and explosive fuel gases
  2. Toxic atmospheres, such as caused by hydrogen sulfide gas, and
  3. Lack of oxygen.

4.4E Physical injuries in manholes can be caused by:
  1. Restricted space,
  2. Uneven and slippery footing,
  3. Defective metal rungs for entry and exist,
  4. Dropping or tossing tools in and out of manholes, and
  5. Sharp objects.

Answers to questions on page 135.

4.4F Personal cleanliness is the best means of protection from diseases when working in a manhole.

4.4G To protect yourself from insects when working in a manhole, always inspect the manhole before entry.

4.4H To protect yourself from drowning, watch your step at all times, especially when working near or in large flows. Wear life jackets and use lifelines if the flow in the sewer is capable of washing a fallen or unconscious operator away and if the operator will fit into the downstream pipe.

Answers to questions on page 146.

4.5A Safety equipment recommended for use when operators are required to enter a manhole include:
  1. Self-contained breathing apparatus (use if necessary or carry a five-minute escape air pack),
  2. Safety harness with lifeline, tripod and winch,
  3. Portable atmospheric alarm unit,
  4. Ventilation blower with hose,
  5. Manhole enclosure,
  6. Ladder or tripod with winch,
  7. Ropes and buckets,
  8. Hard hats,
  9. Protective clothing,
  10. Cones and barricades,
  11. First-aid kit,
  12. Soap, water, paper towels and a litter bag, and
  13. Clean clothes.

4.5B The gas detection device should be either capable of continuously withdrawing samples of the atmosphere from the manhole or equipped with a probe or sensor that is lowered into the manhole and tests for (1) explosive or flammable gases, (2) hydrogen sulfide, and (3) percentage of oxygen. The device should have an audible or visible alarm that will warn when flammable gases exceed 20 percent of the lower explosive limit (LEL), when hydrogen sulfide concentration exceeds 10 ppm, or when oxygen drops below 19.5 percent.

4.5C Hydrogen sulfide gas is a very toxic gas that is commonly found in wastewater collection systems.

Answers to questions on page 148.

4.6A Health conditions that should be considered before entering a manhole include:
  1. Good health,
  2. No hangover, not under influence of alcohol or drugs,
  3. Good physical condition,
  4. No open sores, infections, irritations, and
  5. Current immunizations.

4.6B Topics discussed during the briefing before manhole entry should include:
  1. Safety aspects of job,
  2. Order of doing tasks to accomplish job, and
  3. Emergency procedures.

Answers to questions on page 153.

4.7A The minimum crew when someone enters a manhole is three. One person enters the manhole and two must be standing by topside.

4.7B The person standing by in the safety enclosure should carefully watch the person working in the manhole. The manhole worker's responses and actions can help indicate if the operator is suffering from lack of oxygen or fatigue. If there are any questions regarding safety, the operator should be brought up immediately.

4.7C The minimum level of oxygen in air for safe breathing is 19.5 percent.

4.7D After leaving a manhole, an operator should change clothes and wash thoroughly *BEFORE* going home.

Answers to questions on page 160.

4.8A The first rule that applies to electrical systems is, *"IF YOU ARE NOT QUALIFIED, DO NOT, UNDER ANY CIRCUMSTANCES, ATTEMPT TO WORK ON ELECTRICAL SYSTEMS."*

4.8B The "closed loop" similarity between hydraulic and electrical systems refers to the fact that in electrical systems the electrons want to return to the source, which is commonly referred to as ground. In hydraulic systems, the pressure in the pipe also wants to return to a zero pressure state.

4.8C When working with electrical circuits, provide isolation between you and the ground by using rubber mats, rubber boots, or leather gloves.

Answers to questions on page 161.

4.9A If noise levels cannot be controlled within acceptable limits, operators must be provided with and must use approved ear plugs, muffs, and/or personal protective equipment.

4.10A The different types of materials that can cause fires are ordinary combustibles, flammable liquids, electricity and metals.

4.10B The different types or classes of fires can be extinguished by the following methods:

CLASS	METHOD OF EXTINGUISHING
A	Water
B	Foam, carbon dioxide, dry chemicals
C	Carbon dioxide, dry chemicals
D	Carbon dioxide

4.10C Fire fighting equipment and extinguishers should be inspected on a regular basis such as every 3 or 6 months and after each use.

Answers to questions on page 169.

4.11A The four basic elements of a hazard communication program include:
1. Determine hazardous materials,
2. Obtain chemical information and hazardous conditions,
3. Properly label hazards, and
4. Train operators.

4.11B The general categories of hazardous materials include:
1. Corrosives,
2. Toxics,
3. Flammables and explosives,
4. Asphyxiants,
5. Harmful physical agents, and
6. Infectious agents.

4.11C The purpose of the MSDS sheet is to have a readily available document to be used for training and as an immediate reference, since it includes information on common names, safe exposure level, what the effects of exposure are, what the symptoms of exposure are, whether it is flammable, what type of first aid should be taken, and other information.

4.11D The label on a hazardous material must indicate:
1. All hazards to which employees are exposed,
2. Symptoms of exposure,
3. Appropriate emergency treatment,
4. Proper conditions for safe use, and
5. Precautions against exposure.

OBJECTIVE TEST

Chapter 4. SAFE PROCEDURES

Please mark correct answers on answer sheet as directed at the end of Chapter 1. There may be more than one correct answer to each question.

1. Hazardous tasks performed by collection system operators include
   1. Filing records for future use.
   2. Maintaining supplie in a store room.
   3. Routing traffic around work sites.
   4. Unplugging stopped up sewers.
   5. Working in confined spaces.
2. Characteristics that make collection system equipment difficult to drive include
   1. Difficult to handle.
   2. Improper tire pressure.
   3. Inadequate maintenance.
   4. Limited visibility.
   5. Reduced braking effectiveness.
3. Elements of defensive driving include
   1. Being aware of what's going on around you.
   2. Considering weather conditions.
   3. Driving at the speed limit.
   4. Having your vehicle under control.
   5. Tailgating the vehicle in front of you.
4. Important factors to be considered when determining how to control traffic around a job site include
   1. Lane closures.
   2. Pedestrian walkways.
   3. Residential area.
   4. Speed of traffic.
   5. Time of day.
5. Upon arrival at a job site, the FIRST task for a collection system operator is to
   1. Clear the stoppage.
   2. Inspect the manhole.
   3. Look for a place to park vehicles.
   4. Notify the homeowner who phoned in the problem.
   5. Start digging up the street to get to the problem.
6. Traffic can be diverted and routed around a job site by the use of properly located
   1. Barricades.
   2. Cones.
   3. Sewer pipe.
   4. Shovels.
   5. Signs.
7. Hazards encountered by collection system operators in manholes include
   1. Drowning.
   2. Frostbite.
   3. Infections.
   4. Sunburn.
   5. Toxic gases.
8. Hazardous atmospheres an operator may encounter when entering a manhole include
   1. Corrosive conditions.
   2. Explosive conditions.
   3. Infectious gases.
   4. Oxygen depletion.
   5. Toxic gases.

9. An oxyen deficiency is defined as an atmosphere containing oxygen at a concentration of less than ____ percent by volume.
   1. 10.0
   2. 14.7
   3. 19.5
   4. 21.0
   5. 21.9

10. Recommended methods of entry into manholes include the use of
    1. Aluminum ladders.
    2. Heavy, sturdy ladders.
    3. Metal rungs installed in maholes.
    4. Rope ladders.
    5. Tripods with winches.

11. The atmosphere in a manhole must be tested continuously whenever someone is in the manhole because
    1. A flammable liquid could be dumped into the sewer and turn to gas as it passes through the manhole.
    2. An atmosphere deficient in oxygen could move down the sewer and enter the manhole.
    3. Natural gas from a leak could seep into the sewer and enter the manhole.
    4. The atmospheric alarm unit could fail.
    5. Ventilation may be inadequate.

12. Hydrogen sulfide gas is hazardous to operators because it can cause
    1. A toxic atmosphere.
    2. An explosive or flammable mixture.
    3. Cleaning equipment to fail.
    4. Corrosiv conditions.
    5. Olfactory fatigue.

13. Items that must be checked before entering a manhole include
    1. Atmosphere in manhole.
    2. Briefing on safe procedures.
    3. Equipment.
    4. Health of operator entering manhole.
    5. Sequence of tasks.

14. After leaving a manhole, an operator should
    1. Change clothes and wash thoroughly before going home.
    2. Go straight home.
    3. Test for explosive gases and oxygen deficiency.
    4. Turn on blower to ventilate manhole.
    5. Use a deodorant.

15. Explosive gas mixtures can develop in collection systems due to the presence of oxygen and
    1. Carbon monoxide.
    2. Methane.
    3. Nitrogen.
    4. Propane.
    5. Solvents.

16. The toxic gas most likely to be encountered in a collection system is
    1. Carbon dioxide.
    2. Carbon monoxide.
    3. Hydrogen sulfide.
    4. Methane.
    5. Nitrogen.

17. Hazards that may be encountered by collection system operators as a result of contact with electricity include
    1. Blindness
    2. Burns.
    3. Death.
    4. Explosion.
    5. Physical injury.

18. What causes the most harm to the human body?
    1. Amps
    2. Current
    3. Ohms
    4. Resistance
    5. Voltage

19. Essential elements of a ground fault interrupter include
    1. Circuit breaker.
    2. Circuit interrupting section.
    3. Differential transformer.
    4. Electronic amplifying section.
    5. Fuse.

20. Explosive or ignitable mixtures of gases may be found in
    1. Force mains.
    2. Gravity sewers.
    3. Ground fault interrupters.
    4. Underground vaults.
    5. Wet wells.

21. Approved methods of protecting collection system operators from excesive noise levels includes
    1. Cotton.
    2. Ear plugs.
    3. Hard hat.
    4. Muffs.
    5. Mufflers on equipment.

22. Electric fires can be extinguished by using
    1. Carbon dioxide.
    2. Carbon tetrachloride.
    3. Metals.
    4. Reverse current.
    5. Water.

23. Information regarding a hazardous chemical found on an MSDS sheet includes
    1. Cost of chemical.
    2. Effects of exposure.
    3. First aid measures.
    4. Safe exposure level.
    5. Symptoms of exposure.

24. The purposes of collection system operator training under worker "Right-To-Know" laws include
    1. Awareness of the hazard communication standard.
    2. Improving operators how to deal with emergency situations involving hazardous materials.
    3. Teaching operators how to deal with emergency situations involving hazardous materials.
    4. Training in use of the labeling format.
    5. Understanding of information available on MSDS sheet.

End of Objective Test

CHAPTER 5

INSPECTING AND TESTING COLLECTION SYSTEMS

by

George Freeland

Revised by

Bob Rentfro

TABLE OF CONTENTS

Chapter 5. Inspecting and Testing Collection Systems

Page

OBJECTIVES 179

GLOSSARY 179

LESSON 1

5.1 Reasons for Inspecting and Testing 181

5.2 Inspecting Collection Systems 181

- 5.21 Types of Collection System Problems 181
- 5.22 Inflow and Infiltration 182
  - 5.221 Detection and Correction of Inflow 182
  - 5.222 Identification and Correction of Infiltration 183
  - 5.223 Exfiltration 183

LESSON 2

5.3 Inspection of Manholes 185

- 5.31 Objective of Manhole Inspection 185
- 5.32 Safety 185
- 5.33 Equipment Required 185
- 5.34 Manpower 185
- 5.35 Procedure 185
- 5.36 Frequency of Manhole Inspections 186
- 5.37 Sample Inspection Forms 186

LESSON 3

5.4 Closed Circuit Television Inspections (CCTV) 191

- 5.41 Use of Television 191
  - 5.411 Purposes of Televising Collection Systems 192
  - 5.412 Actions Possible from CCTV Inspection Information 192
- 5.42 Equipment and Manpower 192
  - 5.421 Equipment and Components Required for Televising 192
  - 5.422 Manpower 199

5.43 Procedure 199
  5.431 Setting Up a CCTV Operation 199
  5.432 Logging and Recording Television Inspections 205
  5.433 TV Log Sheet Explanation 208
  5.434 Special Precautions in Televising Collection System 215
  5.435 Shutting Down After Completion of the Pipe Run 220
  5.436 Final Check of Television Survey and Footage Test 220
  5.437 Removal of TV Equipment from Manholes and Footage Test 222
5.44 Purchase of Closed Circuit TV Equipment 223
5.45 Photographing the Television Monitor Picture 223
5.46 Use of Newer TV Equipment 224
5.47 Use of 3D Photography 224

LESSON 4

5.5 Smoke Testing 225
  5.51 Purpose 225
  5.52 Equipment 225
  5.53 Preparations 227
  5.54 Manpower 228
  5.55 Operation 228
  5.56 Recording 229
  5.57 Other Considerations When Smoke Testing 229

LESSON 5

5.6 Dye Testing 233
  5.61 Purpose 233
  5.62 Equipment 233
  5.63 Operation 233
5.7 Pipeline Lamping 233
  5.71 Purpose 233
  5.72 Equipment 234
  5.73 Manpower 234
  5.74 Operation 234
  5.75 Comments 234
5.8 Air and Water Testing 234
SUGGESTED ANSWERS 235
OBJECTIVE TEST 238

APPENDIX

5.9 Closed Circuit Television Equipment Details 240
  5.91 Uses of Closed Circuit TV 240
    5.911 Inspection 240
    5.912 Maintenance 240
    5.913 Rehabilitation Tool 240
  5.92 Experience of Others and Observations from Demonstrations 240
  5.93 The Decision: Use a Contractor or Purchase Equipment 241
  5.94 Important Components of TV Inspection Equipment 241
    5.941 Camera 241
    5.942 TV Cable 241
    5.943 Video Monitor 241
    5.944 TV Cable Reel 241
    5.945 Measure Meter 241
    5.946 System Control Unit 241
    5.947 Light Head Assembly 241
    5.948 Skids and Tow Cables 241
    5.949 Miscellaneous Items 242
  5.95 Economics 242
5.10 Codes for TV Inspection, Defects and Actions/Responses 242
5.11 Additional TV Inspection Equipment Information 242

OBJECTIVES

Chapter 5 INSPECTING AND TESTING COLLECTION SYSTEMS

After completion of Chapter 5 you should be able to do the following:

1. Inspect new sewers and replacement sewers for installation as planned by examining line and grade, joint and junction adequacy, and proper installation of manholes and appurtenances,
2. Test for leaks in joints, taps, sewers and manholes of existing facilities,
3. Find legal, illegal, unauthorized and improper connections,
4. Locate and determine the seriousness of inflow, infiltration, exfiltration and diversion flow problems,
5. Identify and evaluate damage due to corrosion, cracking, crushing, subsidence (soil settling), root intrusion, stoppages, washouts and improper connections,
6. Provide meaningful reports to supervisors so they can assign priorities in order to develop cost-effective maintenance or corrective action programs, and
7. Effectively use the inspecting and testing tools and procedures described in this chapter including closed circuit television, smoke testing, dye testing and pipeline lamping.

GLOSSARY

Chapter 5 INSPECTING AND TESTING COLLECTION SYSTEMS

CABLE STRAIN RELIEF
CABLE STRAIN RELIEF

A mesh type of device that grips the cable to prevent any strain on the power cable from reaching the connections to the camera and the light.

CORROSION
CORROSION

The gradual decomposition or destruction of a material due to chemical action, often due to an electrochemical reaction. Corrosion starts at the surface of a material and moves inward, such as the chemical action upon manholes and sewer pipe materials.

ELEVATION ELEVATION

The height to which something is elevated, such as the height above sea level.

FAIR LEAD PULLEY FAIR LEAD PULLEY

A pulley that is placed in a manhole to guide a TV camera, electric cables, and the pull cable into the sewer when inspecting pipelines.

FLOAT LINE FLOAT LINE

A length of rope or heavy twine attached to a float, plastic jug or parachute to be carried by the flow in a sewer from one manhole the next. This is called "stringing the line" and is used for pulling through winch cables, such as for bucket machine work or closed- circuit television work.

FOCAL LENGTH FOCAL LENGTH

The distance of a focus from the surface of a lens (such as a camera lens) to the focal point.

HERTZ (HURTS) HERTZ

The number of complete electromagnetic cycles or waves in one second of an electrical or electronic circuit. Also called the frequency of the current. Abbreviated Hz.

LAMPING LAMPING

Using reflected sunlight or a powerful light beam to inspect a sewer between two adjacent manholes. The light is directed down the pipe from one manhole. If it can be seen from the next manhole, it indicates that the line is open and straight.

OFFSET OFFSET

Displacement. An abrupt bend in an object, such as a sewer line, by which one part is turned aside and out of alignment.

PRE-CLEANING PRE-CLEANING

Sewer line cleaning, commonly done by high velocity cleaners, that is done prior to TV inspection of pipeline to remove grease, slime, and grit to allow for a more clear and accurate identification of defects and problems.

SADDLE CONNECTION SADDLE CONNECTION

A building service connection made to a sewer main with a device called a saddle.

SEWER GAS SEWER GAS

(1) Gas in collection lines (sewers) that results from the decomposition of organic matter in the wastewater. When testing for gases found in sewers, test for lack of oxygen and also for explosive and toxic gases.

(2) Any gas present in the wastewater collection system, even though it is form such sources as gas mains, gasoline and cleaning fluid.

SUBSIDENCE SUBSIDENCE

A sink or a depressing of soil. The tendency to move downward (sometimes caused by pumping of groundwater) such as the gradual settling of a specific area of the soil which causes the settling of underground utilities.

SURCHARGE SURCHARGE

Sewers are surcharged when the supply of water to be carried is greater than the capacity of the pipes to carry it. The surface of the wastewater in manholes rises above the top of the sewer pipe, and the sewer is under pressure or a head, rather than at atmospheric pressure.

TAG LINE TAG LINE

A line, rope or cable that follows equipment through a sewer so the equipment can be pulled back out if it encounters an obstruction or becomes stuck. Equipment is pulled forward with a pull line.

TV LOG TV LOG

A written record of internal conditions during a sewer line TV inspection.

WATER TABLE WATER TABLE

The upper surface of the portion of the ground wholly saturated with water.

CHAPTER 5. INSPECTING AND TESTING COLLECTION SYSTEMS

(Lesson 1 of 5 Lessons)

5.1 REASONS FOR INSPECTING AND TESTING

Wastewater collection systems are intended to be a reliable method of conveying wastewater from individual dischargers to wastewater treatment plants. Inspection and testing are the techniques used to gather information to develop operation and maintenance programs to insure that new and existing collection systems serve their intended purposes on a continuing basis. Inspection and testing are necessary to do the following:

1. Identify existing or potential problem areas in the collection system,
2. Evaluate seriousness of detected problems,
3. Locate the position of problems,
4. Provide clear, concise, and meaningful reports to supervisors regarding problems.

Two major purposes of inspecting and testing are to prevent leaks in the wastewater collection system from developing and to identify existing leaks so they can be corrected. The existence of leaks in a wastewater collection system is a serious and often expensive problem. When a sewer is under a water table, infiltration can take place and occupy valuable capacity in the sewer and the downstream treatment plant. Sewers located above a water table can exfiltrate, allowing raw wastewater to pollute soil and groundwater. A health hazard is created when the wastewater reaches a nearby well or open ditches where children and pets play. Leaks in sewers also invite root intrusion which eventually can cause stoppages, damage to the sewer and infiltration or exfiltration depending on the elevation of the water table. The location and elimination of leaks in a wastewater collection system is one of the major concerns of wastewater collection system operators and their supervisors.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 235.

5.1A Why should wastewater collection systems be inspected and tested?

5.1B Why are leaks a problem in wastewater collection systems?

5.2 INSPECTING COLLECTION SYSTEMS

Inspection of wastewater collection systems is a very important phase of the operation and maintenance of collection systems. When inspecting, look for the causes of problems or the start of a potential problem. Once a problem has been identified, its exact location must be determined. The size and kind of problem must be identified so the problem can be solved. This section outlines the kinds of problems found in collection systems.

5.21 Types of Collection System Problems

Collection system problems may be created or caused by design, construction, sewer use, operation, maintenance or outside forces or events. Major sources of problems include:

1. Design-related deficiencies. Design must consider and make provisions for special local conditions such as ability of soil to support pipe and manhole weights, shifting soils, and vibrating or crushing forces from traffic. Other design-related problems include inadequate provisions for joint flexing and pipe bedding.

COLLECTION SYSTEM PROBLEMS
GE
TYPES
FIVE
PROBLEMS

2. Improper installation. Plans and specifications must be followed. Improper line, grade and joint installation and short cuts in bedding, connections and backfilling can cause future problems. Other examples of improper installation include use of inferior or damaged materials.
3. Inadequate sewer-use ordinances, communication between dischargers to sewers and enforcers of ordinances, and enforcement.
4. Improper inspection and enforcement of tap-ins or service connections by individuals, plumbers or contractors that result in illegal connections and/or inflow.
5. Changing patterns of population shifts and activities that result in *SURCHARGING*[1] some sections of the sewer system and excessive residence time of wastewater and solids in other sections.
6. Disaster or contingency situations such as explosions, earthquakes, *SUBSIDENCE*,[2] war or wastewater flow shifts of major proportions.
7. Problems of a recurrent nature in the collection system such as the accumulation of grease, debris and trash that result in stoppages or restrictions that reduce the capacity of the sewer. Also of great concern to many of the "sun belt" cities is the infestation of insects such as cockroaches. Although they do not affect the workings of a collection system, their presence does pose public relation considerations that must be dealt with daily.
8. Problems characteristic of the region such that hasten the deterioration of sewers, for example, climate, high sulfate content in waters, high soil or wastewater temperatures, rapid root growth and mucky soils.
9. Poor coordination between local agencies. Street construction and repair as well as activities of other utility agencies should be coordinated. Consideration must be given to previous installations of utilities. Provisions must be made for early warnings of accidents or a workable system for handling regular "accidental" dumps into the sewers.
10. Problems related to a tired and frequently forgotten wastewater collection system.

Once the source or cause of a problem has been identified, provisions can be made to correct this problem and also to prevent similar problems from occurring in the future.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 235.

5.2A What is the purpose of inspecting wastewater collection systems?

5.2B List the major sources of wastewater collection system problems.

5.22 Inflow and Infiltration

Infiltration and inflow, while overlooked in many collection systems for decades, have now gained recognition as a major defect that can cause failure of a collection system. In most cases, this failure results in hydraulic overloads (too much water) of the collection system or the wastewater treatment plant.

1. In the case of a collection system, hydraulic overloads result in surcharged manholes, manhole overflowing and exposure of a community to the diseases and pollutants carried by a wastewater collection system.

2. In the case of a wastewater treatment plant, infiltration and inflow can result in plant loads in excess of the plant capacity. By-passing raw wastewater to the environment has been the only answer in the past, but this practice is no longer allowed.

5.221 Detection and Correction of Inflow

Inflow detection and correction depend upon the type and source of inflow causing the problem. Inflow is wastewater that enters a sewer as a result of a deliberate connection and through broken or deteriorated pipes.

1. Inflow

Inflow requires a combination of flow studies and an inspection of buildings or private property if they appear to be the location of the source. While closed circuit television inspections can reveal service connections with heavy discharges of clear water, or unabated discharges not typical of a domestic waste discharge, it is a slow process. This procedure requires the camera to observe a service connection for as long as twenty minutes to determine type and quantities of flow. If a location appears to be discharging greater than typical flows, contact residents of the home or building. Determine if water use is taking place and if the use is the only source of the flows observed.

Corrections to eliminate inflow require a sewer-use ordinance rather than sewer maintenance projects. In such cases, a provision for enforcement of waste discharges to a collection system should be part of local codes or ordinances and transferred to a legal or enforcement activity, such as an industrial waste section. A wastewater collection system maintenance crew should never be required to do more than report and provide reliable proof of inflow violations by a property owner.

Where illegal inflows are detected and certified, the maintenance crew may be required to certify as to the effectiveness of possible corrections or to accurately measure flows for billing purposes.

2. Surface Drainage

Sources of surface drainage are best located by smoke testing (Section 5.5). These can partially be corrected when the collection system crew has the proper authority. On private property removal of improper connections, such as roof leaders being connected to a wastewater collection system, should be the responsibility of some agency of a municipality or district other than the collection system crew. Other sources of surface drainage include water entering the collection system through unsealed manholes located at points lower than the surrounding area grade.

---

[1] *Surcharge. Sewers are surcharged when the supply of water to be carried is greater than the capacity of the pipes to carry it. The surface of the wastewater in manholes rises above the top of the sewer pipe, and the sewer is under pressure or a head, rather than at atmospheric pressure.*

[2] *Subsidence. A sink or depression of soil. The tendency to move downward (sometimes caused by pumping of groundwater) such as the gradual settling of a specific area of the soil which causes the settling of underground utilities.*

TRAFFIC ROUTING
HI! PLEASE TURN BACK AND REVIEW SECTION 4:3 ON PAGE 116

MANHOLE HAZARDS
HI! PLEASE TURN BACK AND REVIEW SECTION 4.4 ON PAGE 124

5.422 Manpower

Usually the televising crew consists of three people: one TV operator and two sewer service workers.

1. TV Operator

   The TV operator is the lead person of the three-party crew whose job it is to observe the TV monitor and control the progress of the TV camera from the operator's station.

   This operator must be thoroughly experienced in the inspection and repair of sanitary sewers. This person must be able to recognize and evaluate conditions found in the pipe. A knowledge of TV electronics is not required but the ability to successfully troubleshoot the equipment is desireable.

2. Sewer Service Worker, Wastewater Collection

   Helps to make initial set up. Then is stationed at the far manhole to:

   a. Operate the pulling hand winch, or

   b. Observe the operation of the power winch, or

   c. Disconnect the self-propelled camera from the power supply so the power cable can be retracted.

3. Sewer Service Worker, Wastewater Collection

   Helps to make initial set up. Then is stationed at the rear of the TV unit or truck to:

   a. Operate the return hand winch, or

   b. Operate the electric controls on the reel return.

   c. Workers at both manholes must also observe "down hole" cable guides or protection devices used to protect the power and winch cable from sharp edges.

4. Additional help is required when working in heavy traffic and congested areas.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 236.

5.40A Why must testing and inspecting collection systems be done thoroughly and on a regular basis?

5.41A What are the advantages of closed circuit television inspection of wastewater collection systems?

5.41B List the kinds of information that can be obtained from a television inspection of a sewer system.

5.42A How many people are usually on a collection system televising crew?

5.43 Procedure

5.431 Setting up a CCTV Operation

In this example procedure, the TV camera will be used to inspect a sewer between two adjacent manholes. *THE CAMERA SHOULD ALWAYS BE PULLED IN THE DIRECTION OF FLOW OR FROM THE UPSTREAM MANHOLE TO THE DOWNSTREAM MANHOLE.* By moving a camera downstream, any debris in the pipe should be washed away in front of the camera and any build up on the back of the camera should be removed as the camera moves along.

However, there are instances when the TV camera can be pulled upstream or against the flow such as in a new line (not yet in service) or in a sewer line containing minimal flows. When doing this, it is important that the data be recorded on a properly designed "log sheet" (see example Figure 5.9, page 206). The TV inspection report or "log sheet" must contain information and a diagram showing the direction of camera travel in the section being televised. A detailed explanation on the logging of information on the inspection report will be presented in Section 5.432.

Sewer lines should be cleaned prior to televising by using either high velocity cleaners, water jet-vacuum (combination machines), power rodders, bucket machines or balling. Cleaning is generally necessary to remove sludge, grit, roots and grease which could interfere with the operation of the TV camera and cover up cracks, leaks, and open joints.

Stringing of the pull cable into the sewer line can be accomplished by using any of the above machines or by using a parachute with an extractor fan. Lightweight string lines can also be floated from one manhole to another by using a small rubber ball and then attaching the cable to be inserted into the line. Whether or not a sewer should be cleaned before televising depends on the diameter and condition of the sewer. Cleaning gets rid of obstructions, thus allowing better flow conditions, or identifies the location of obstructions that could cause problems during TV inspection.

If the sewer to be televised is flowing so full that the TV camera will be submerged, special considerations must be evaluated. Upstream lines can be plugged temporarily to reduce flows but should only be done by experienced personnel and only after careful study to assure that property damage will not occur due to the flow restriction. If a plug is inserted in a sewer to reduce flows downstream in order to televise the sewer, have someone observe the level of the water in an upstream manhole. Be sure the water does not become so high that plumbing fixtures in nearby homes will overflow and flood the homes. An additional safeguard would be to set up "by-pass pumping" of the flows during the time required for the TV inspection of the sewer line. A second alternative is to schedule the work to be done during normal low flow times such as between midnight and five a.m. Also the plugging of sewers will cause downstream flows and conditions to change which could interrupt downstream flow measurements, sampling, testing, and wastewater treatment processes; therefore, always notify the treatment plant operators and industrial waste inspectors whose activities could be affected by your actions.

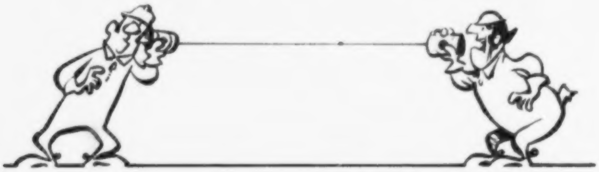
The following sections contain typical steps that should be followed to inspect a sewer using closed circuit TV. *ALWAYS FOLLOW THE DIRECTIONS PROVIDED BY THE MANUFACTURER OF YOUR TV EQUIPMENT.*

1. Safety. Refer to Sections 4.3, "ROUTING TRAFFIC," AND 4.4, "MANHOLE HAZARDS," for safe procedures to route traffic around job site and enter a manhole.

TRAFFIC ROUTING
HI! PLEASE TURN BACK AND REVIEW SECTION 4.3 ON PAGE 116

MANHOLE HAZARDS
HI! PLEASE TURN BACK AND REVIEW SECTION 4.4 ON PAGE 124

2. String the sewer from manhole to manhole. The objective is to bring the pull winch cable from the downstream manhole, through the sewer, to the upstream manhole for the attachment of the camera. Any of the methods used to pre-clean sewer lines can be an effective means to string the line. The most positive way is with the use of a high velocity cleaner or power rodder. "Floating" lines for stringing is possible but this method is the least desireable due to the effects of low spots, roots and partial blockages in preventing the line from completing the procedure.
3. While the line is being strung through the sewer, the pull winch is moved to the downstream manhole and set up.
4. When used, the telephone cable and system are laid out from manhole to manhole and a worker at each manhole puts on the telephone headset. Voice communication is tested to make certain communications between manholes are adequate. In situations where traffic over the telephone cable is heavy, one may consider the use of a CB radio base station (at the operator's station) and a walkie talkie for the sewer worker at the far hole.



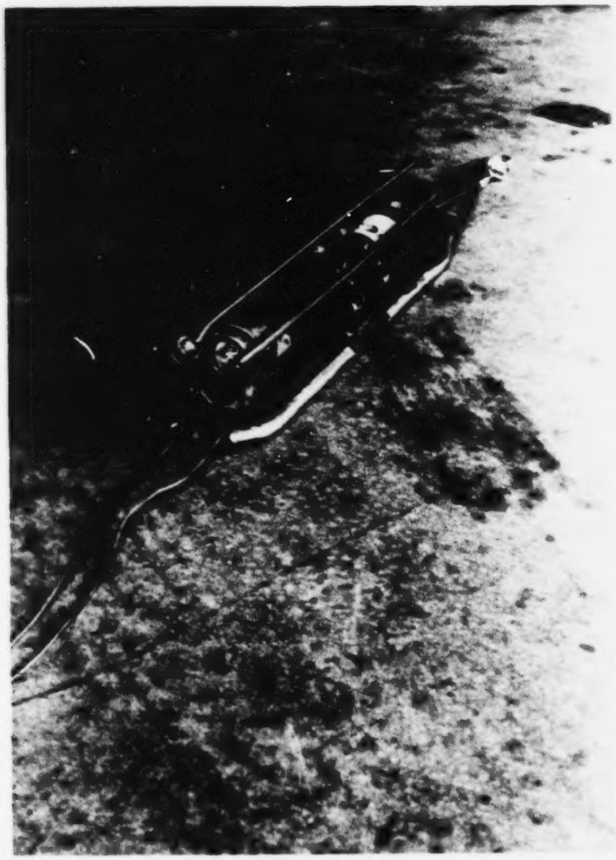
5. Also while the line is being strung, the generator is started and the system tested for adequate power in volts and for proper cycles *(HERTZ)*[4] of the power supply. Most systems operate on a voltage range of 110-125 volts and 60-cycles per second (Hertz) (59-61 range) of AC (alternating electrical current). Meters indicating both of these power values are generally included in the power control module.
   a. If voltage is too high or too low, the control module should have a multiple tap transformer with marked settings to increase or decrease the voltage input to the system.
   b. Keep the generator tuned and set by experienced generator technicians to avoid problems.
6. As soon as the power generator has been started, inspected and adjusted as necessary for proper power supply, the operator must turn off the master switch of the power control unit or such switches as are provided to the camera circuit and lighting circuit.
7. The crew makes necessary changes on the camera skid assembly to prepare the assembly for the size of pipe to be televised. The proper skid assembly is important because the TV camera lens must be as close as possible to the center of the pipe when the camera moves down the pipe. Connect the tow and tag line bridles at this time (Figure 5.7).
8. The operator brings the end of the television transmission cable into the location where both the front of the camera and the television monitor can be seen. The lens cover is removed from the camera. Protection of the camera lens depends on the type of tube. Silicon tubes do not need to be protected from sunlight or bright light while vidicon tubes must be protected.

CAUTION: NEVER PLACE AN EXPOSED CAMERA LENS WITH A VIDICON TUBE WHERE BRIGHT LIGHT OR SUNLIGHT CAN ENTER IT. THE OPTICAL LENS IS FOCUSED DIRECTLY ONTO THE PHOTOSENSITIVE COATING OF THE VIDICON TUBE AND DIRECT SUNLIGHT CAN CAUSE BURNING WITH PERMANENT DAMAGE. CONSULT MANUFACTURER'S MANUAL OF INSTRUCTIONS BECAUSE SOME TYPES OF CAMERAS CAN BE DAMAGED BY BRIGHT REFLECTED LIGHT.

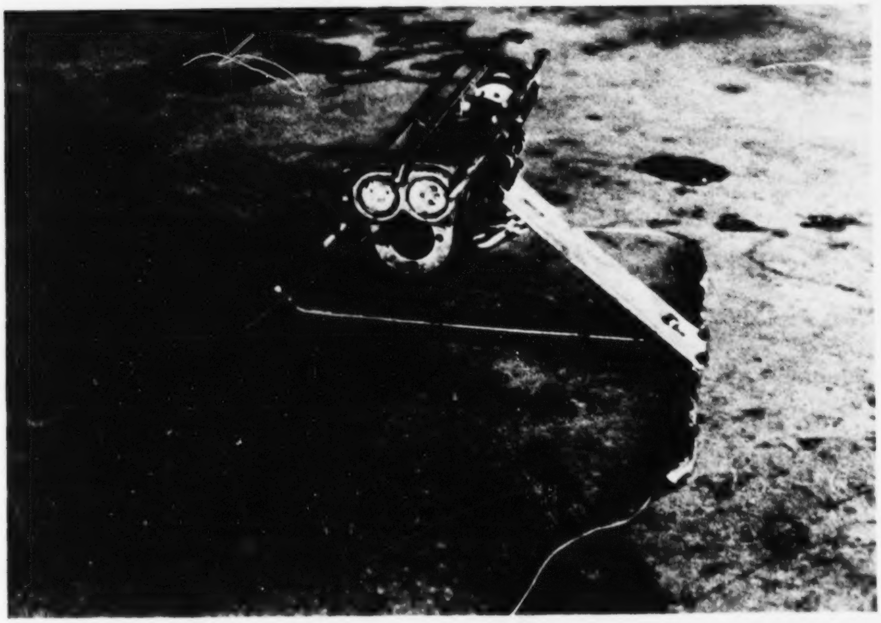
9. The operator connects the leads of the television transmission cable to the camera and turns on necessary switches to activate the camera power and video circuit, including turning on the television monitor. Do not activate the camera lighthead circuit, but make certain that it is off or set to zero on the intensity control.

---

[4] *Hertz (Hurts). The number of complete electromagnetic cycles or waves in one second of an electrical or electronic circuit. Also referred to as the frequency of the current. Abbreviated HZ.*



TV camera ready for a small diameter sewer



TV camera ready for large diameter sewer
NOTE: Tow and tag line bridles attached to lower skids.

Fig. 5.7 Sewer line TV camera ready for operation
(Courtesy of CUES)

10. As soon as a picture appears in the monitor, the operator focuses the camera for a pre-set distance, dependent upon the diameter of the pipe being televised from the camera. Some of the newer cameras available are equipped with an automatic focus switch located on the operator's panel and can be adjusted automatically after the TV camera is placed inside the sewer line.

    a. Sewer inspection cameras are provided with various types of wide-angle lenses ranging from 33°, 53°, 64° and 90°. Each one of these different wide-angle lenses works with a different focal distance in any selection pipe size. A 90° lens has a picture edge only eight and a half inches away in a 12-inch pipe. In the same pipe, a 33° lens must look almost two feet down the pipe before a picture is available.

    b. Where such distances are unknown, consult the manufacturer's instructions.

11. Before placing the camera in the sewer line, check the camera light power supply to be sure all connections are secure. Once this has been done, turn off all power to the TV camera.

    The lighting circuit only should be tested and turned off before any heat can develop in the light head.

12. The operator replaces the lens cover on the camera.

13. Making certain that all power to the camera assembly is off, the operator takes the camera to the manhole where the television inspection is to start.

    Attach the cable strain relief to the tag line bridle (when applicable) and keep the electrical connections intact.

14. At the close manhole, a worker attaches the pull winch cable that has been strung through the sewer line tow cable (swivel connnection) of the TV camera. The camera is now ready to be placed into the sewer line. The TV rollers should be put in place so the line will not be cut or damaged.

MANHOLE HAZARDS
HI! PLEASE TURN BACK AND REVIEW SECTION 4.4 ON PAGE 124

15. At the close manhole, a worker will have made the necessary preparations to enter the manhole safely. This will include the wearing of the safety harness, the venting of the manhole and the testing of the atmosphere. Worker topside at the close manhole wears a telephone headset (or uses a walkie talkie) for communications with the pull winch operator.

Many times the TV camera can be inserted in the sewer while the crew remains topside. The camera is placed on the skid assembly and lowered into the manhole using the pull cable. Also the camera is positioned using pull cables.

16. As soon as the worker is down the manhole and ready, the operator passes the TV camera assembly down to the worker for placement in the flow lines.

    a. If the pull winch cable was not attached above ground, it now must be connected to the front tow bridle of the camera. The worker must also check the connections on the power transmission cable, *CABLE STRAIN RELIEF*,[5] and the tag line winch.

    b. The worker then removes the lens cover from the camera and directs the pull winch operator to take in the slack cable.

    c. As the pull winch cable slack disappears, the worker guides the cable into the sewer line. The cable and camera are pulled from the manhole into the downstream sewer line to a point where the tips of the rear skids are even with the outer edge of the manhole. The worker then gives the command to the pull winch operator to stop!

    d. The camera is then turned on by the TV operator and all systems checked for proper operation. Be sure the *POWER IS OFF BEFORE* inspecting the connections, cables and TV camera. *NEVER* touch a TV camera in a manhole unless all power has been switched off. If any final adjustments are required, they are made at this time through a coordinated effort of the TV operator and the worker still in the manhole. The camera power is then turned off and the worker exits the manhole.

17. Once the assistant is out of the manhole, the operator returns to the operating station and opens necessary switches to power the camera and light. As soon as the picture and the lighting are satisfactory, the operator announces that all is ready.

---

[5] *Cable strain relief. A mesh type of device that grips the cable to prevent any strain on the power cable from reacing the connection to the camera and the light.*

18. When the operator indicates that all is ready, the pull winch operator and the assistant install necessary fair lead equipment in the two manholes and locate the winches over the manholes.
    a. As each operator completes the fair lead installation, they report their readiness to the TV operator.
    b. The operator is then cleared to tell the pull winch operator to pull away.

NOTE

FAIR LEAD EQUIPMENT IS NOT INSTALLED UNTIL THE OPERATOR HAS A SATISFACTORY PICTURE OF THE PIPELINE. IN SOME TYPES OF CAMERAS, AN IRIS OR F-STOP ADJUSTMENT MUST BE MADE TO THE CAMERA LENS AFTER INSIDE PIPE LIGHTING HAS BEEN TESTED. THIS SHOULD BE DONE BEFORE INSTALLATION OF FAIR LEAD EQUIPMENT AT THE UPSTREAM MANHOLE.

CAUTION

THE CAMERA MUST **NEVER** BE TOUCHED IN A MANHOLE **UNLESS ALL POWER HAS BEEN SWITCHED OFF**. SOME OLDER STYLE CAMERAS HAVE A CASE GROUNDING CIRCUIT WHICH COULD CAUSE EXTREMELY HIGH VOLTAGE IN THE CASE IN CERTAIN TYPES OF MALFUNCTIONS

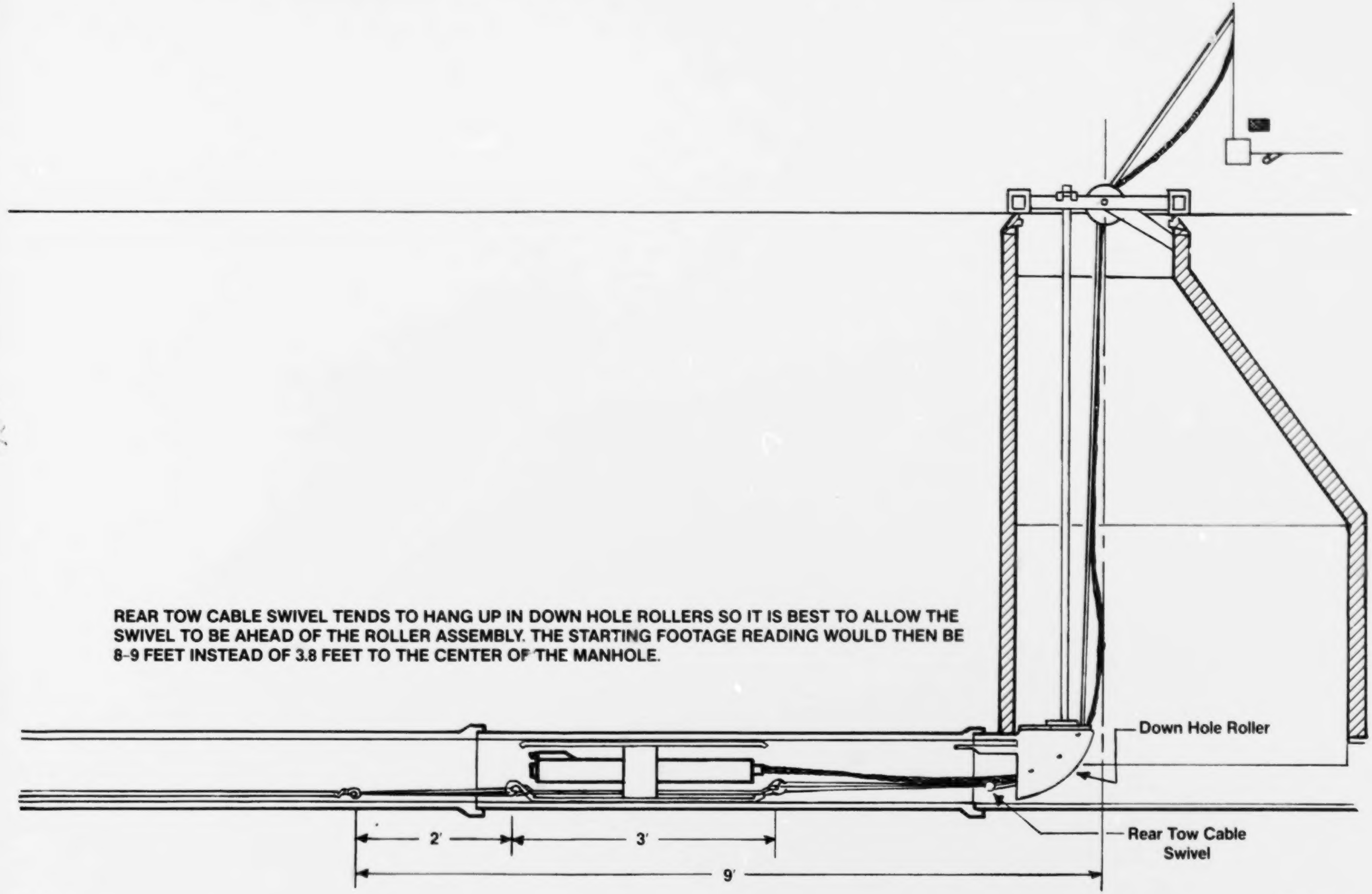
19. Slack in the power cable is pulled back through the footage meter and the footage meter set for proper reading. All footage readings must be estimated as closely as possible and should always start at the *CENTER* of the manhole so repair crews will always measure from the same point. Since the TV camera has been inserted into the sewer and is ready to move down the line. Since the TV camera has been inserted into the sewer and is ready to move down the line, the focal point is generally nine (9) feet from the center of the beginning manhole. The footage meter is set to read this number prior to beginning the inspection (Figure 5.8). This is extremely important so that all measurements are taken from the *center* of the starting (upstream) manhole.
20. When all is ready, the TV operator directs the operator at the pull winch to pull the camera. For directions, certain commands are agreed upon ahead of time. These can be determined to direct the proper operation of the winches. The following commands are provided only as suggestions:
    a. "GO AHEAD" from the operator at the TV monitor means for the camera to be winched through the sewer at regular speed. This speed in feet per second or minute will vary with the experience of the operator.
    b. "AHEAD SLOW" or "SLOWLY" means to reduce the speed of the camera's progress. This is generally done when some object is being approached and it may be desirable to stop for a polaroid photo or operation of the video recorder.
    c. "STOP" means exactly that. The pull winch operator stops pulling.
    d. "WE ARE GOING TO PULL BACK ______ FEET" means that the tag line winch is going to be used to pull the camera backwards. The pull winch operator must be advised of this action. The operator must remove the crank from the pull winch and shift the rachet (if the winch is so provided) to permit cable to be pulled backwards. Pulling back without letting the winch operator know can cause the crank to rotate rapidly, possibly striking the operator's hands or arms and causing pain or injury on certain types of equipment.

WE AREGOING
TO BACK
FI FEET

    e. "WE ARE TAKING THE CAMERA BACK" means the camera is going to be pulled back out of the line.

CAUTION: WHENEVER PULLING A CAMERA BACK MORE THAN ONE FOOT, THE SLACK MUST BE TAKEN OUT OF THE POWER CABLE BY THE SERVICE WORKER STATIONED AT THE STARTING (UPSTREAM) MANHOLE WHILE THE CAMERA IS MOVING BACKWARDS. FAILURE TO DO THIS CAN PERMIT THE POWER CABLE TO BECOME TANGLED WITH THE CAMERA AND SKID ASSEMBLY AND CAUSE EXCESSIVE WEAR POINTS AND POSSIBLE SEVERE DAMAGE TO THE POWER CABLE ON CERTAIN TYPES OF EQUIPMENT.

21. There are two essential rules that must never be violated:
    a. While the camera is being moved through the line, the operator must never stop looking at the monitor picture. Any obstruction that could wedge or damage the camera or the light must be seen in time to stop the camera's forward progress. If the picture is lost for any reason, the forward progress of the camera must be stopped. If the picture cannot be reestablished again, the camera must be pulled backwards out of the line.
    b. If communications with the operator at the pull winch are lost, progress must be stopped immediately. For most crews, a shouted signal from one member indicates a loss of this communication.



REAR TOW CABLE SWIVEL TENDS TO HANG UP IN DOWN HOLE ROLLERS SO IT IS BEST TO ALLOW THE SWIVEL TO BE AHEAD OF THE ROLLER ASSEMBLY. THE STARTING FOOTAGE READING WOULD THEN BE 8-9 FEET INSTEAD OF 3.8 FEET TO THE CENTER OF THE MANHOLE.

Down Hole Roller
Rear Tow Cable Swivel
2′
3′
9′

Fig. 5.8 Adjustment of footage meter

22. If the pull winch operator begins to experience excessive drag on the cable, this fact must be immediately reported to the TV operator and the operation halted to check the cable guide devices ("downhole rollers") for wedging of the cable. Pull the camera back a few feet to see what could cause the drag or possible wedging. An out of round pipe can cause wedging. If a camera and skid assembly become locked or wedged in a pipe and the pull cables break, the sewer must be dug up to recover the camera. Therefore, it is very important that the TV operator and the worker operating the pull winch at the far (downstream) manhole develop an exact understanding of voice communications among themselves.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 236.

5.43A Why should the TV camera *ALWAYS* be pulled from the upstream to the downstream manhole?

5.43B What should a TV inspection crew do first when they arrive at a sewer to be inspected with a TV camera?

5.43C Is the TV pull winch located at the upstream or downstream manhole?

5.43D Why must the proper skids be used with the TV camera?

5.43.E How is the pull winch cable kept from rubbing on the pipe at the downstream manhole?

5.43F Where in the pipe line should the footage meter be set to read zero?

5.43G What are two essential rules that must never be violated while the camera is moving through the line?

5.43H Why must extreme care be taken to prevent the TV camera from becoming wedged in the pipe?

5.432 Logging and Recording Television Inspections

A television inspection of a pipeline requires that all data are observed and recorded. The operator of the TV monitor must determine what is to be recorded, photographed, or video taped. As an operator you also should have the camera's progress halted every time you take your eyes off the monitor to record information.

1. Most television inspection records are placed on a standard log (see example on Figure 5.9). Each operator may desire to slightly redesign a log sheet especially for their particular needs. However, there is certain basic information that should be included on sewer line television report forms. This information includes agency name, date, location, map number, TV operator's name, type of pipe and identification of section being televised (manhole numbers). Other information that could be helpful yet not critical include a sketch showing the direction of flow in the sewer line, the direction of the TV inspection, a north arrow, identification number of equipment being used, video tape identification number, "new work" or "in use" sewer designation, and name of inspector or concerned individual present. Coded initials and symbols or numbers are used for simplicity and to save time. Some of the suggested codes are:

   — SC Service connection. Quadrant number of position of entry is usually added. Some operators use a time clock notation rather than a quadrant number. (See Figure 5.9, sample log.)

   — R Roots. Generally followed by number indicating growth. (See Figure 5.10, root rating chart.)

   — I Infiltration. May be followed by number to indicate estimated gallons per minute and a quadrant number to show point of entry. To learn how to estimate infiltration flows, if possible, observe typical flows at locations or in a lab where actual flows can be measured. By comparing estimated flows with actual flows, accurate flow estimates can be made by experienced operators in the field.

   — DL-G Dirty Line, grease or soap cake. For sand or silt deposits DL-S, for rocks DL-K.

   — C/B Cracked or broken place. This can have a remark indicating possible collapse of the pipe for extensive damage of this type.

   — OJ Offset joint. Can be followed by a number or fraction to indicate inches or fractions of an inch out of line.

   — GDS Grade defect, starting point.

   — GDE Grade defect, ending point.

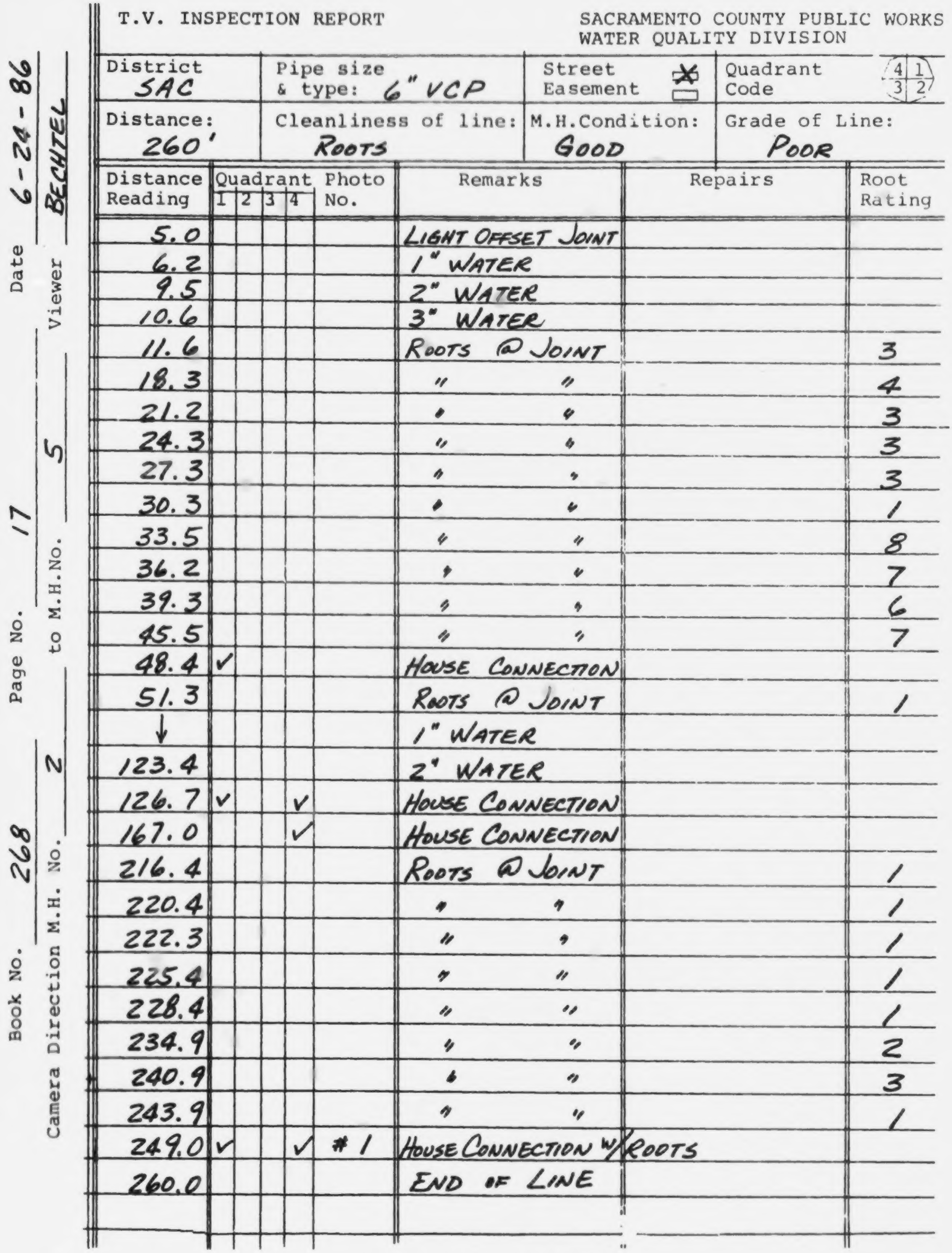
   — CUW Camera under water. Point where lens was more than half covered by water.

   — COW Camera out of water. Point where lens was less than half covered by water.

See the appendix at the end of this chapter for a three-letter coding system for sewer inspection, defects and actions/responses (Section 5.10).

   Combinations of these are used to provide information about one location. Example: 263 SC-1-R2-I5 = "Station 263, Service Connection from Quadrant One, Roots to rating two, infiltration at approximately five gallons per minute, all from service lateral."

2. Polaroid still photographs, black and white, are often used to support log entries. Infiltration points, bad offsets, damaged laterals, root growths, and broken pipe locations are examples. When each photo is taken, the footage and log entry are recorded on the back of the photo (where a video-footage readout system (Fig. 5.6) is not provided or used) (Figures 5.11 and 5.12).
   a. Polaroid cameras have an automatic exposure device that automatically makes a good picture from the light in the television monitor. There must be a minimum of other light sources that can affect the camera's light adjustment process. In some situations, a special hood may be necessary to eliminate other light sources. This hood must permit the front face of the camera, as well as the electric eye port, to be exposed to the monitor picture.



Date 6-24-86

Viewer BECHTEL

Page No. 17

to M.H.No. 5

Book No. 268

Camera Direction M.H. No. 2

T.V. INSPECTION REPORT

SACRAMENTO COUNTY PUBLIC WORKS
WATER QUALITY DIVISION

District SAC	Pipe size & type: 6" VCP	Street ☒ Easement ☐	Quadrant Code 4 1 / 3 2
Distance: 260'	Cleanliness of line: ROOTS	M.H.Condition: GOOD	Grade of Line: POOR

Distance Reading	Quadrant 1	2	3	4	Photo No.	Remarks	Repairs	Root Rating
5.0						LIGHT OFFSET JOINT		
6.2						1" WATER		
9.5						2" WATER		
10.6						3" WATER		
11.6						ROOTS @ JOINT		3
18.3						" "		4
21.2						" "		3
24.3						" "		3
27.3						" "		3
30.3						" "		1
33.5						" "		8
36.2						" "		7
39.3						" "		6
45.5						" "		7
48.4	✓					HOUSE CONNECTION		
51.3						ROOTS @ JOINT		1
↓						1" WATER		
123.4						2" WATER		
126.7	✓			✓		HOUSE CONNECTION		
167.0				✓		HOUSE CONNECTION		
216.4						ROOTS @ JOINT		1
220.4						" "		1
222.3						" "		1
225.4						" "		1
228.4						" "		1
234.9						" "		2
240.9						" "		3
243.9						" "		1
249.0	✓			✓	# 1	HOUSE CONNECTION W/ ROOTS		
260.0						END OF LINE		

Fig. 5.9 TV inspection report

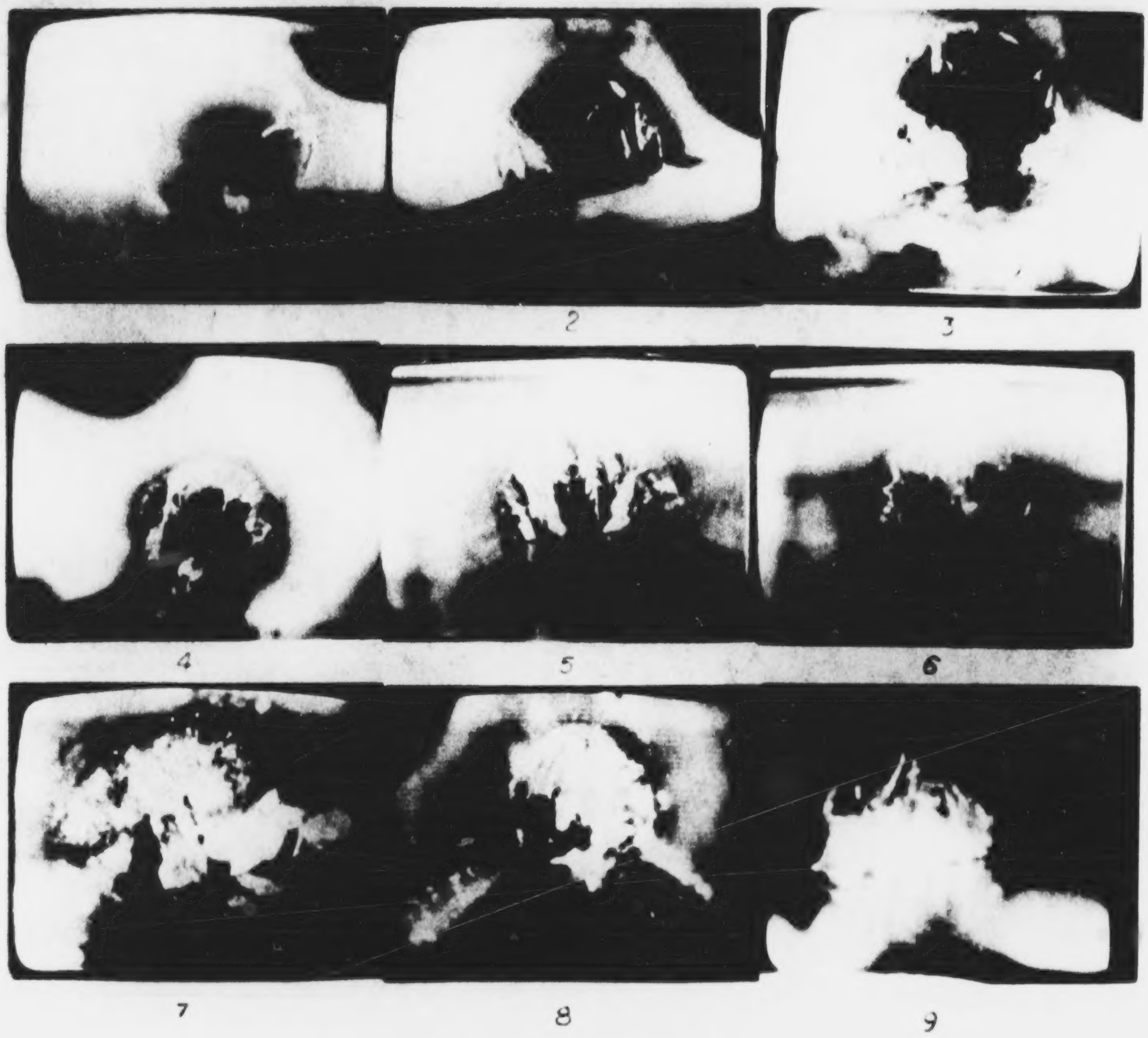


Fig. 5.10 Root rating system
(Courtesy of Sacramento County, Division of Water Quality)

b. To be effective for focus, a polaroid camera must have a close-up lens and sighting kit.

c. Bright lighting behind a polaroid camera can cause reflections in the glass face of the monitor. Adequate curtains or shrouding should be provided to block out background light.

3. Video tape recordings can be used in place of or in addition to a polaroid camera. Video tapes are able to provide a better record of some types of pipe situations. While most video tape recorders have the ability to record the voice of the TV operator when describing the condition of the sewer, defects observed, and the footage of the situation being viewed, voice records are not required when a video footage readout system is provided and used. Video footage readout systems are helpful, but a TV operator's actual description and comments are very useful when replaying the video tape in an office for someone who is not very familiar with the conditions in the collection system. These systems cannot replace the expertise of an experienced operator who can accurately describe the condition of the pipe in the audio portion of the video tape. In addition, when background noises such as autombile traffic, industrial areas and airport traffic areas, make it impossible to use the audio at the time of the actual inspection, the TV operator can replay the tape later at a more quiet site and "dub" in the voice comments at that time.

Another feature usually provided with video recording equipment is a selector switch. This three position switch permits televising without recording, televising and recording at the same time, and instant replay of recorded tape after tape rewind. If the operator sees an object or situation to be video taped, the operator starts the recorder, talks into the microphone to describe the situation, footages or other remarks, and then stops the television camera progress after the TV camera has passed the problem area. The operator may then rewind the video tape to the place it was when the recording was started, switch to "VIR" (Video Instant Replay) and replay the recording in the monitor to make certain the record and words desired are correct. The operator can then switch back to televise, switch off the recorder and proceed on down the pipe.

Some of the advantages of a video recording system are:

a. The system records motion while still photography freezes motion. In an infiltration situation, the ability to record water flow in action for later viewing has definite advantages.

b. Where a pipe is off-grade, starting the video recording operating during the full passage is desirable. When the supervisor reviews the tape, the supervisor can determine the seriousness of the situation and the necessary corrective action. If a video footage readout system is used, footages are automatically recorded on the tape. When no video footage readout system is provided, the operator should call out footages at frequent and regular intervals into the audio recording system of the tape recorder.

NOTE: IN COLLECTION SYSTEMS WITH DIPS OR SAGS WHERE WATER IS ALLOWED TO STAND, SOLIDS CAN SETTLE OUT AND CREATE A DANGEROUS NUISANCE BY PRODUCING HYDROGEN SULFIDE AS WELL AS BY CAUSING HIGH MAINTENANCE COSTS. VIDEO TAPE DOCUMENTATION OF THE EXTENT AND SEVERITY OF THESE LOCATIONS WILL PROVIDE THE NECESSARY INFORMATION SO ECONOMICAL AND QUICK REPAIR OR CORRECTION OF THE SITUATION CAN BE MADE.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 237.

5.43I Why should the TV camera be stopped while the operator records data?

5.43J What items are photographed with a polaroid camera?

5.43K What are some of the advantages of using a video tape over a polaroid camera?

5.433 TV Log Sheet Explanation

Different agencies use different approaches to logging TV inspection data. This section illustrates the procedures used by the City of Phoenix.

TV Inspection Report (Figure 5.A) shows the TV log as made out by the TV operator.

Explanation:

Flow direction arrows and TV direction arrows are drawn in as they occur in that specific run.

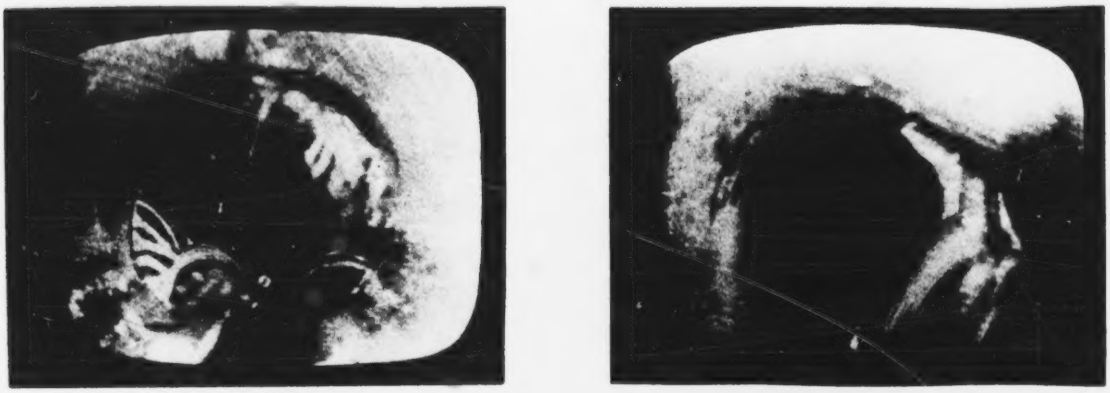
Run is ✓'d as "routine," "complaint" or "new work."

Starting manhole is placed in diagram on the left and ending manhole on the right with actual length of line recorded in center (432 LF).

Starting stationing is always recorded as #0+00 (center of manhole) in the beginning manhole.

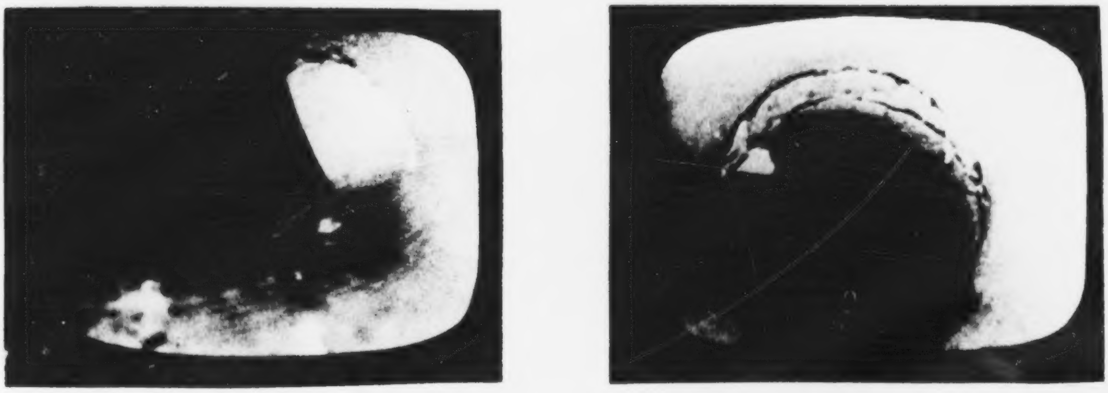
"TN FACT" or "TN TAP" distinguishes between a factory or field tapped service connection into the main.

City of Phenix does not use "quadrant code" - a "severity code" of 1-10 is used, i.e. 3 , 6 , 9 ; this relates to the severity of the condition stated, i.e.; "roots @ joint 5 ." This indicates that the root intrusion is obstructing approximately 1/2 of the diameter of the pipe. In addition, "pipe cracked 9 " would indicate a severely cracked pipe, very near collapse.



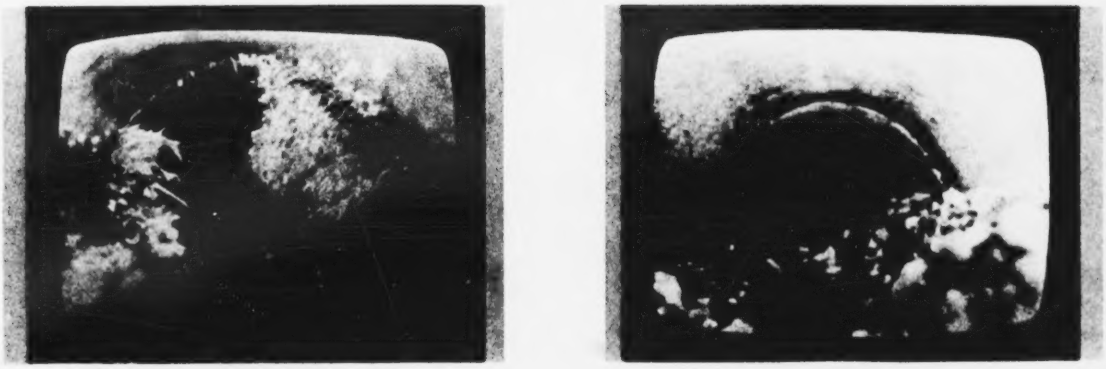
Infiltration at defective pipe joint.

Infiltration or inflow at
defective service connection.



Protruding service tap.

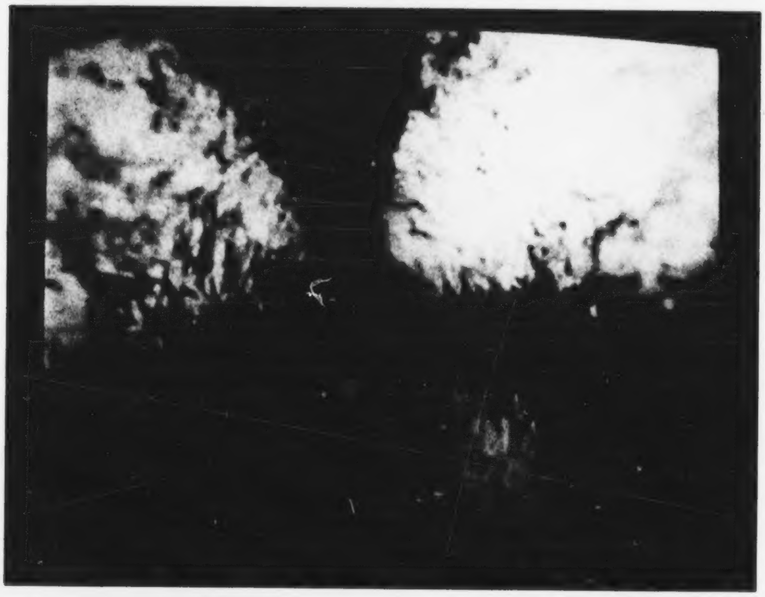
Drop joint.



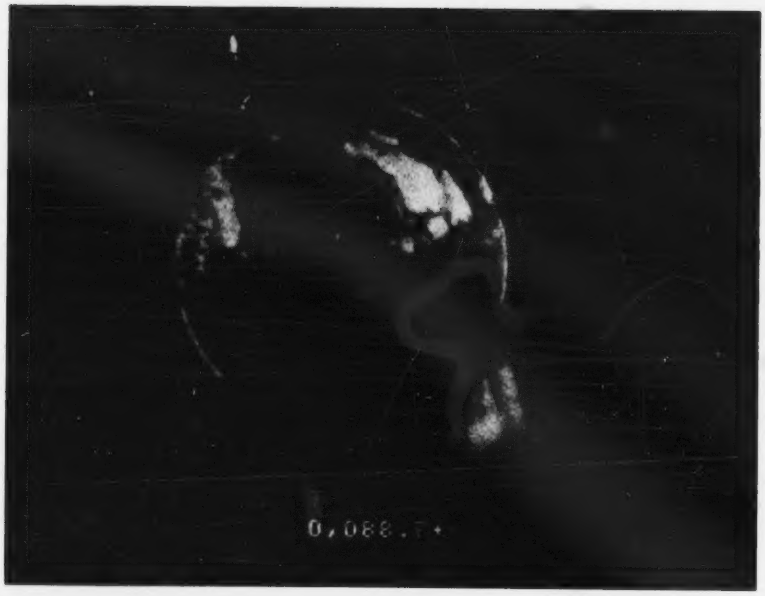
Root intrusion.

Dirty line, gravel and debris.

Fig. 5.11 Typical data available from CCTV sewer inspections

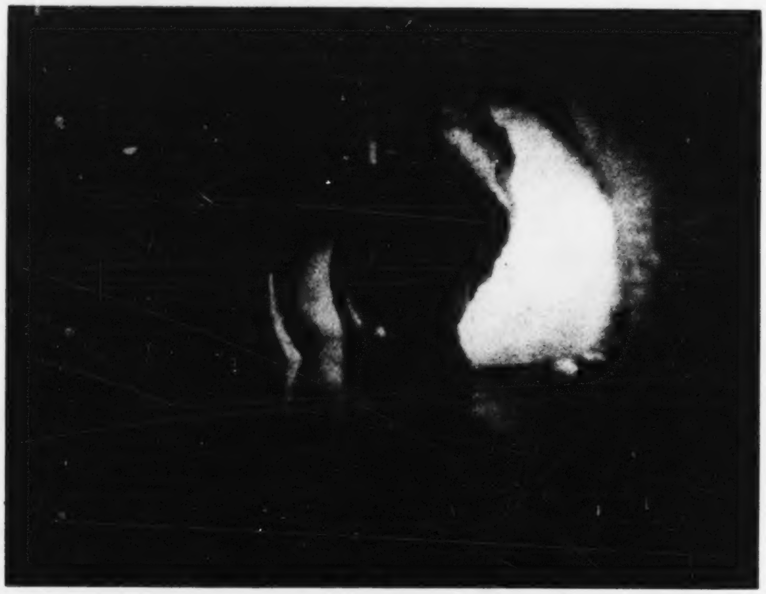


Heavy grease

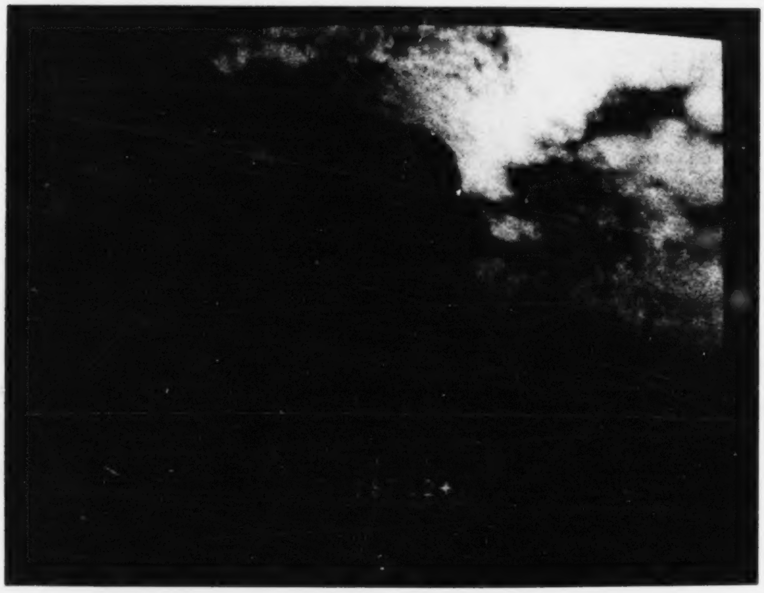


Grease build-up

Fig. 5.11 Typical data available from CCTV sewer inspections (con't.)



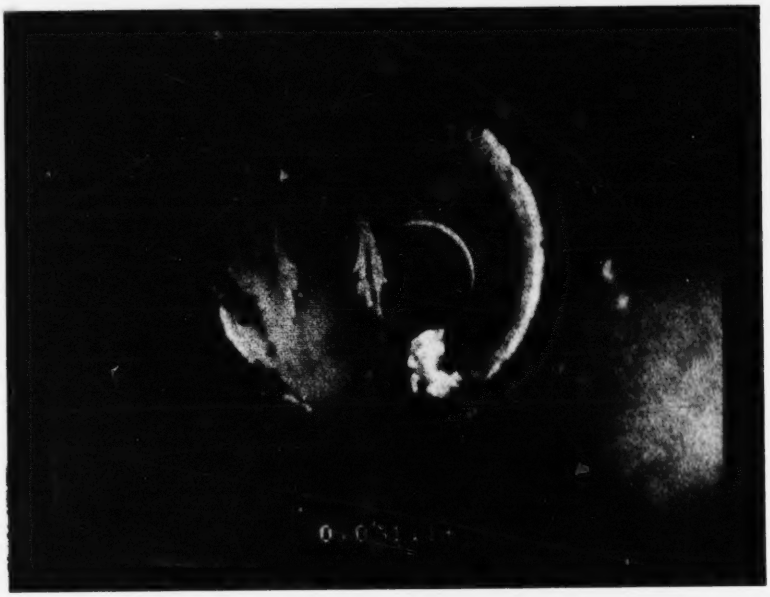
Protruding tap



Detergent build-up

Fig. 5.11 Typical data available from CCTV sewer inspections (con't.)

Roots in PVC pipe



Root intrusion

Fig. 5.11 Typical data available from CCTV sewer inspections (con't.)

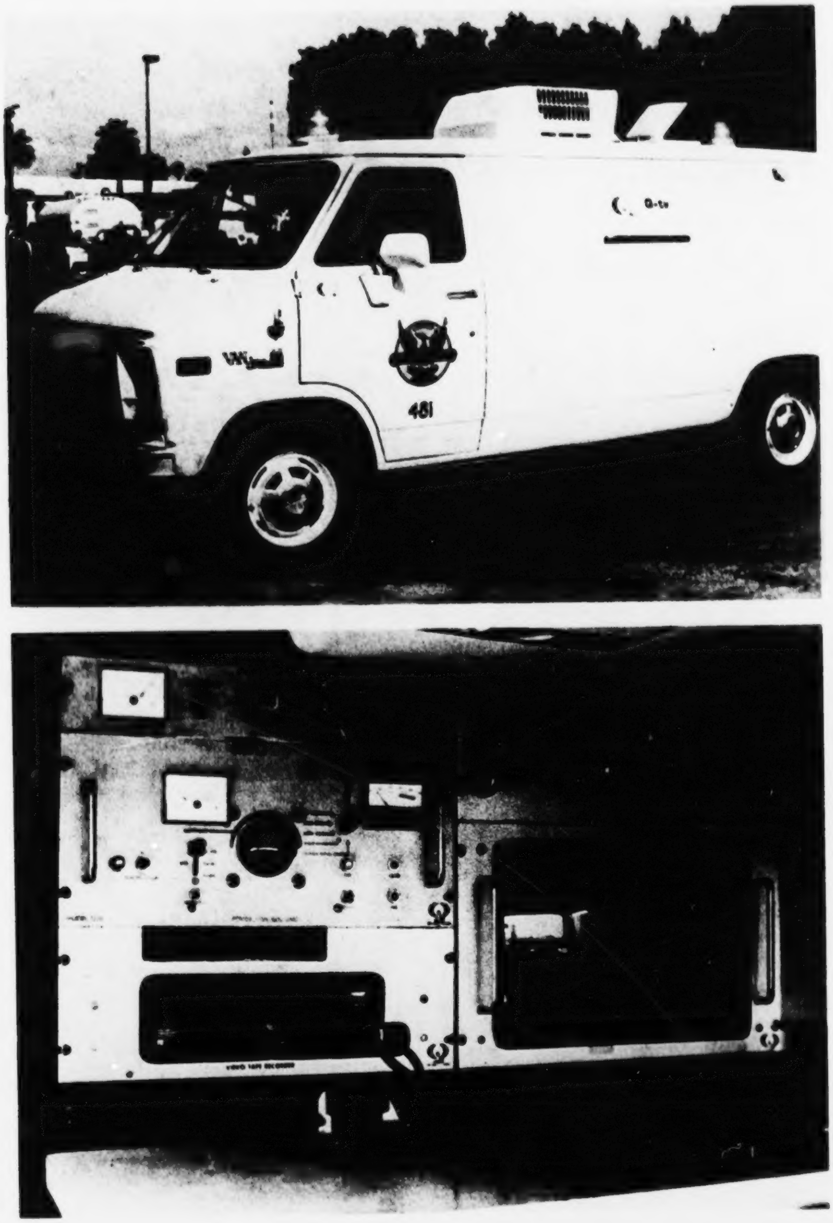
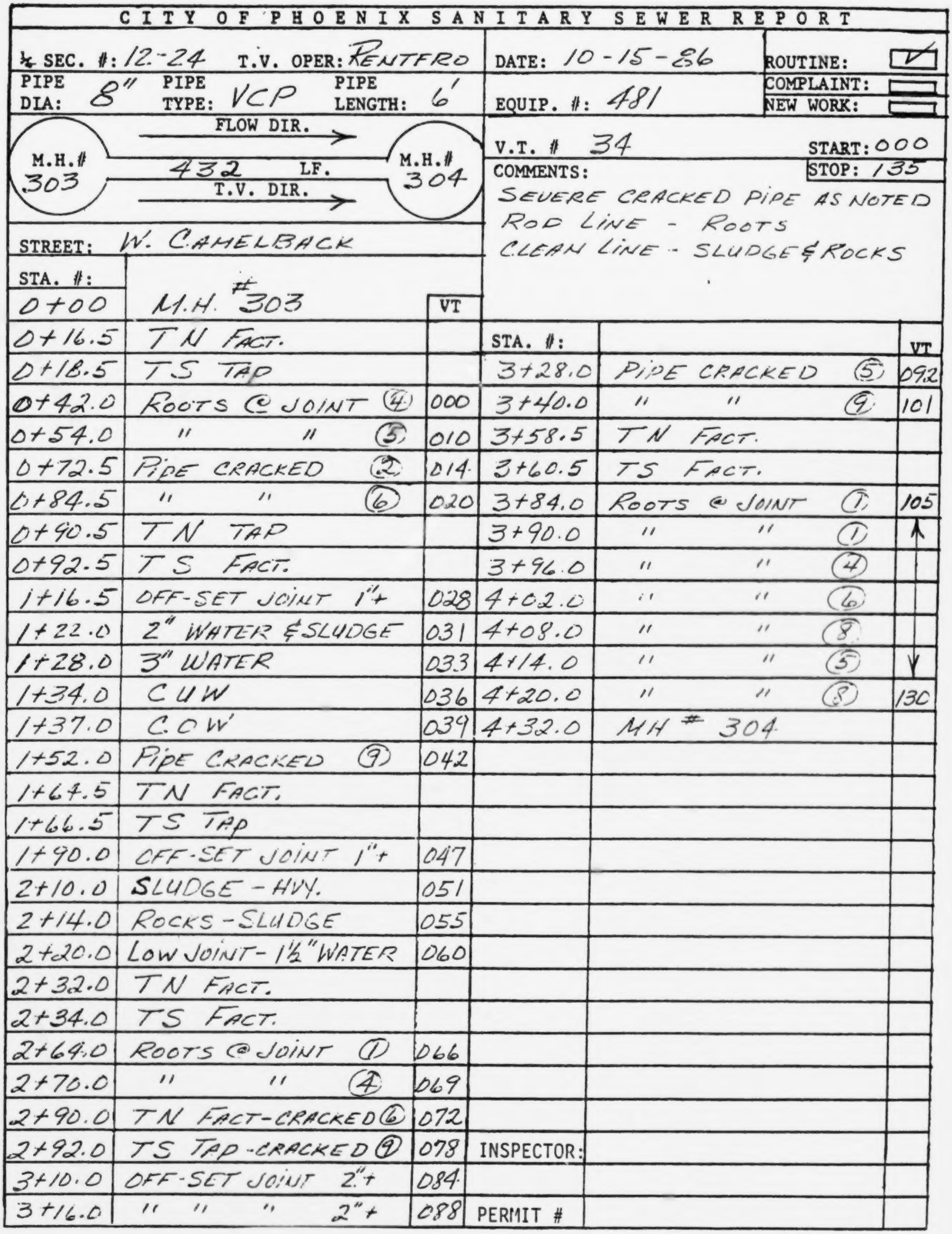


Fig. 5.12 CCTV system van and operator's station



CITY OF PHOENIX SANITARY SEWER REPORT

¼ SEC. #: 12-24 T.V. OPER: RENTFRO
DATE: 10-15-86
ROUTINE: ☑
COMPLAINT: ☐
NEW WORK: ☐
PIPE DIA: 8" PIPE TYPE: VCP PIPE LENGTH: 6'
EQUIP. #: 481

M.H. # 303 — FLOW DIR. → — 432 LF. — T.V. DIR. → — M.H. # 304

V.T. # 34
START: 000
STOP: 135
COMMENTS:
SEVERE CRACKED PIPE AS NOTED
ROD LINE - ROOTS
CLEAN LINE - SLUDGE & ROCKS

STREET: W. CAMELBACK

STA. #:		VT
0+00	M.H. #303	
0+16.5	TN FACT.	
0+18.5	TS TAP	
0+42.0	ROOTS @ JOINT ④	000
0+54.0	" " ⑤	010
0+72.5	PIPE CRACKED ②	014
0+84.5	" " ⑥	020
0+90.5	TN TAP	
0+92.5	TS FACT.	
1+16.5	OFF-SET JOINT 1"+	028
1+22.0	2" WATER & SLUDGE	031
1+28.0	3" WATER	033
1+34.0	CUW	036
1+37.0	COW	039
1+52.0	PIPE CRACKED ⑨	042
1+64.5	TN FACT.	
1+66.5	TS TAP	
1+90.0	OFF-SET JOINT 1"+	047
2+10.0	SLUDGE - HVY.	051
2+14.0	ROCKS - SLUDGE	055
2+20.0	LOW JOINT - 1½" WATER	060
2+32.0	TN FACT.	
2+34.0	TS FACT.	
2+64.0	ROOTS @ JOINT ①	066
2+70.0	" " ④	069
2+90.0	TN FACT - CRACKED ⑥	072
2+92.0	TS TAP - CRACKED ⑨	078
3+10.0	OFF-SET JOINT 2"+	084
3+16.0	" " " 2"+	088

STA. #:		VT
3+28.0	PIPE CRACKED ⑤	092
3+40.0	" " ⑨	101
3+58.5	TN FACT.	
3+60.5	TS FACT.	
3+84.0	ROOTS @ JOINT ①	105
3+90.0	" " ①	↑
3+96.0	" " ④	
4+02.0	" " ⑥	
4+08.0	" " ⑧	
4+14.0	" " ⑤	↓
4+20.0	" " ⑧	130
4+32.0	MH #304	

INSPECTOR:

PERMIT #

Fig. 5.A TV inspection report. Also see reviewed TV inspection report (Figure 5.B)

145-191D
Rev. 4/85

TRAFFIC ROUTING
HI! PLEASE TURN BACK AND REVIEW SECTION 4:3 ON PAGE 116

MANHOLE HAZARDS
HI! PLEASE TURN BACK AND REVIEW SECTION 4.4 ON PAGE 124

5.422 Manpower

Usually the televising crew consists of three people: one TV operator and two sewer service workers.

1. TV Operator

   The TV operator is the lead person of the three-party crew whose job it is to observe the TV monitor and control the progress of the TV camera from the operator's station.

   This operator must be thoroughly experienced in the inspection and repair of sanitary sewers. This person must be able to recognize and evaluate conditions found in the pipe. A knowledge of TV electronics is not required but the ability to successfully troubleshoot the equipment is desireable.

2. Sewer Service Worker, Wastewater Collection

   Helps to make initial set up. Then is stationed at the far manhole to:

   a. Operate the pulling hand winch, or

   b. Observe the operation of the power winch, or

   c. Disconnect the self-propelled camera from the power supply so the power cable can be retracted.

3. Sewer Service Worker, Wastewater Collection

   Helps to make initial set up. Then is stationed at the rear of the TV unit or truck to:

   a. Operate the return hand winch, or

   b. Operate the electric controls on the reel return.

   c. Workers at both manholes must also observe "down hole" cable guides or protection devices used to protect the power and winch cable from sharp edges.

4. Additional help is required when working in heavy traffic and congested areas.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 236.

5.40A Why must testing and inspecting collection systems be done thoroughly and on a regular basis?

5.41A What are the advantages of closed circuit television inspection of wastewater collection systems?

5.41B List the kinds of information that can be obtained from a television inspection of a sewer system.

5.42A How many people are usually on a collection system televising crew?

5.43 Procedure

5.431 Setting up a CCTV Operation

In this example procedure, the TV camera will be used to inspect a sewer between two adjacent manholes. *THE CAMERA SHOULD ALWAYS BE PULLED IN THE DIRECTION OF FLOW OR FROM THE UPSTREAM MANHOLE TO THE DOWNSTREAM MANHOLE.* By moving a camera downstream, any debris in the pipe should be washed away in front of the camera and any build up on the back of the camera should be removed as the camera moves along.

However, there are instances when the TV camera can be pulled upstream or against the flow such as in a new line (not yet in service) or in a sewer line containing minimal flows. When doing this, it is important that the data be recorded on a properly designed "log sheet" (see example Figure 5.9, page 206). The TV inspection report or "log sheet" must contain information and a diagram showing the direction of camera travel in the section being televised. A detailed explanation on the logging of information on the inspection report will be presented in Section 5.432.

Sewer lines should be cleaned prior to televising by using either high velocity cleaners, water jet-vacuum (combination machines), power rodders, bucket machines or balling. Cleaning is generally necessary to remove sludge, grit, roots and grease which could interfere with the operation of the TV camera and cover up cracks, leaks, and open joints.

Stringing of the pull cable into the sewer line can be accomplished by using any of the above machines or by using a parachute with an extractor fan. Lightweight string lines can also be floated from one manhole to another by using a small rubber ball and then attaching the cable to be inserted into the line. Whether or not a sewer should be cleaned before televising depends on the diameter and condition of the sewer. Cleaning gets rid of obstructions, thus allowing better flow conditions, or identifies the location of obstructions that could cause problems during TV inspection.

If the sewer to be televised is flowing so full that the TV camera will be submerged, special considerations must be evaluated. Upstream lines can be plugged temporarily to reduce flows but should only be done by experienced personnel and only after careful study to assure that property damage will not occur due to the flow restriction. If a plug is inserted in a sewer to reduce flows downstream in order to televise the sewer, have someone observe the level of the water in an upstream manhole. Be sure the water does not become so high that plumbing fixtures in nearby homes will overflow and flood the homes. An additional safeguard would be to set up "by-pass pumping" of the flows during the time required for the TV inspection of the sewer line. A second alternative is to schedule the work to be done during normal low flow times such as between midnight and five a.m. Also the plugging of sewers will cause downstream flows and conditions to change which could interrupt downstream flow measurements, sampling, testing, and wastewater treatment processes; therefore, always notify the treatment plant operators and industrial waste inspectors whose activities could be affected by your actions.

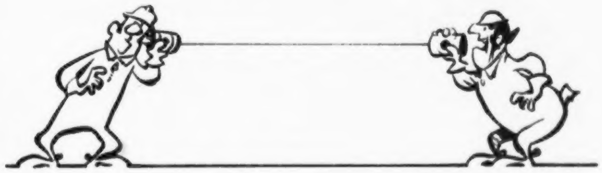
The following sections contain typical steps that should be followed to inspect a sewer using closed circuit TV. *ALWAYS FOLLOW THE DIRECTIONS PROVIDED BY THE MANUFACTURER OF YOUR TV EQUIPMENT.*

1. Safety. Refer to Sections 4.3, "ROUTING TRAFFIC," AND 4.4, "MANHOLE HAZARDS," for safe procedures to route traffic around job site and enter a manhole.

TRAFFIC ROUTING
HI! PLEASE TURN BACK AND REVIEW SECTION 4:3 ON PAGE 116

MANHOLE HAZARDS
HI! PLEASE TURN BACK AND REVIEW SECTION 4:4 ON PAGE 124

2. String the sewer from manhole to manhole. The objective is to bring the pull winch cable from the downstream manhole, through the sewer, to the upstream manhole for the attachment of the camera. Any of the methods used to pre-clean sewer lines can be an effective means to string the line. The most positive way is with the use of a high velocity cleaner or power rodder. "Floating" lines for stringing is possible but this method is the least desireable due to the effects of low spots, roots and partial blockages in preventing the line from completing the procedure.
3. While the line is being strung through the sewer, the pull winch is moved to the downstream manhole and set up.
4. When used, the telephone cable and system are laid out from manhole to manhole and a worker at each manhole puts on the telephone headset. Voice communication is tested to make certain communications between manholes are adequate. In situations where traffic over the telephone cable is heavy, one may consider the use of a CB radio base station (at the operator's station) and a walkie talkie for the sewer worker at the far hole.



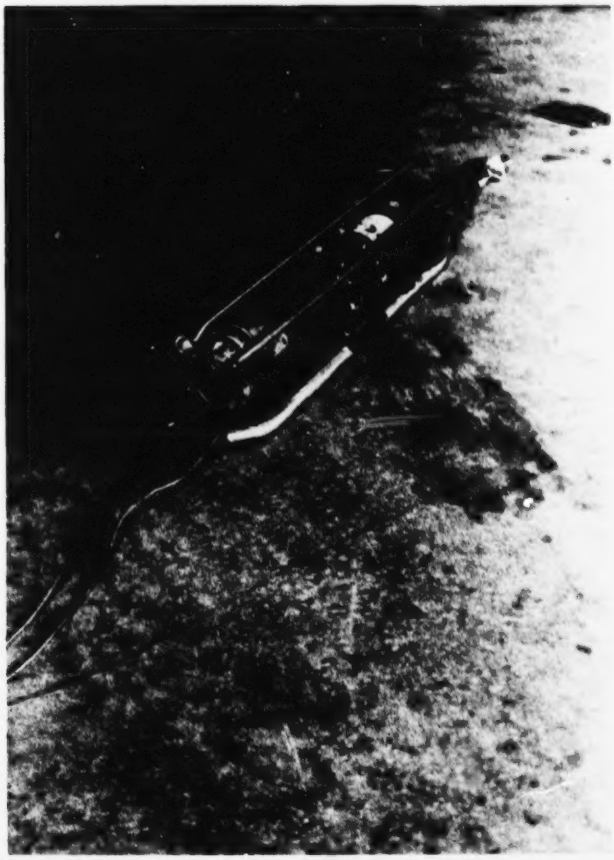
5. Also while the line is being strung, the generator is started and the system tested for adequate power in volts and for proper cycles *(HERTZ)*[4] of the power supply. Most systems operate on a voltage range of 110-125 volts and 60-cycles per second (Hertz) (59-61 range) of AC (alternating electrical current). Meters indicating both of these power values are generally included in the power control module.
   a. If voltage is too high or too low, the control module should have a multiple tap transformer with marked settings to increase or decrease the voltage input to the system.
   b. Keep the generator tuned and set by experienced generator technicians to avoid problems.
6. As soon as the power generator has been started, inspected and adjusted as necessary for proper power supply, the operator must turn off the master switch of the power control unit or such switches as are provided to the camera circuit and lighting circuit.
7. The crew makes necessary changes on the camera skid assembly to prepare the assembly for the size of pipe to be televised. The proper skid assembly is important because the TV camera lens must be as close as possible to the center of the pipe when the camera moves down the pipe. Connect the tow and tag line bridles at this time (Figure 5.7).
8. The operator brings the end of the television transmission cable into the location where both the front of the camera and the television monitor can be seen. The lens cover is removed from the camera. Protection of the camera lens depends on the type of tube. Silicon tubes do not need to be protected from sunlight or bright light while vidicon tubes must be protected.

CAUTION: NEVER PLACE AN EXPOSED CAMERA LENS WITH A VIDICON TUBE WHERE BRIGHT LIGHT OR SUNLIGHT CAN ENTER IT. THE OPTICAL LENS IS FOCUSED DIRECTLY ONTO THE PHOTOSENSITIVE COATING OF THE VIDICON TUBE AND DIRECT SUNLIGHT CAN CAUSE BURNING WITH PERMANENT DAMAGE. CONSULT MANUFACTURER'S MANUAL OF INSTRUCTIONS BECAUSE SOME TYPES OF CAMERAS CAN BE DAMAGED BY BRIGHT REFLECTED LIGHT.

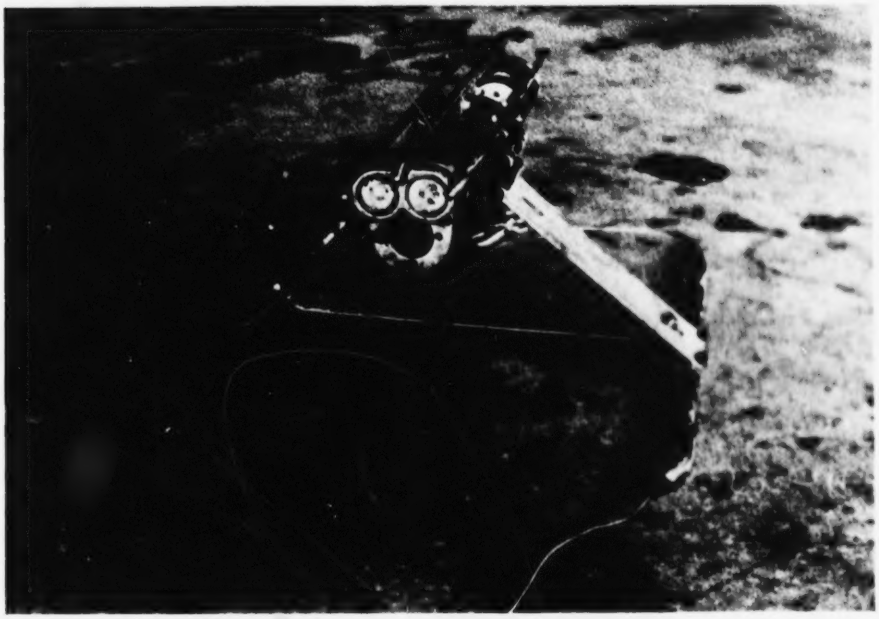
9. The operator connects the leads of the television transmission cable to the camera and turns on necessary switches to activate the camera power and video circuit, including turning on the television monitor. Do not activate the camera lighthead circuit, but make certain that it is off or set to zero on the intensity control.

---

[4] *Hertz (Hurts). The number of complete electromagnetic cycles or waves in one second of an electrical or electronic circuit. Also referred to as the frequency of the current. Abbreviated HZ.*



TV camera ready for a small diameter sewer



TV camera ready for large diameter sewer
NOTE: Tow and tag line bridles attached to lower skids.

Fig. 5.7 Sewer line TV camera ready for operation
(Courtesy of CUES)

10. As soon as a picture appears in the monitor, the operator focuses the camera for a pre-set distance, dependent upon the diameter of the pipe being televised from the camera. Some of the newer cameras available are equipped with an automatic focus switch located on the operator's panel and can be adjusted automatically after the TV camera is placed inside the sewer line.
    a. Sewer inspection cameras are provided with various types of wide-angle lenses ranging from 33°, 53°, 64° and 90°. Each one of these different wide-angle lenses works with a different focal distance in any selection pipe size. A 90° lens has a picture edge only eight and a half inches away in a 12-inch pipe. In the same pipe, a 33° lens must look almost two feet down the pipe before a picture is available.
    b. Where such distances are unknown, consult the manufacturer's instructions.
11. Before placing the camera in the sewer line, check the camera light power supply to be sure all connections are secure. Once this has been done, turn off all power to the TV camera.

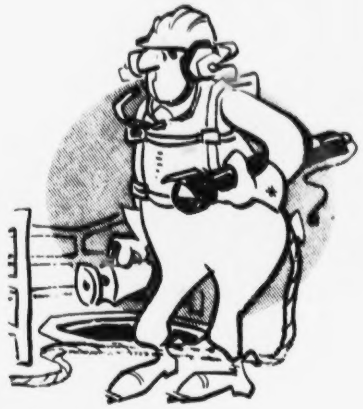
    The lighting circuit only should be tested and turned off before any heat can develop in the light head.
12. The operator replaces the lens cover on the camera.
13. Making certain that all power to the camera assembly is off, the operator takes the camera to the manhole where the television inspection is to start.

    Attach the cable strain relief to the tag line bridle (when applicable) and keep the electrical connections intact.
14. At the close manhole, a worker attaches the pull winch cable that has been strung through the sewer line tow cable (swivel connnection) of the TV camera. The camera is now ready to be placed into the sewer line. The TV rollers should be put in place so the line will not be cut or damaged.

MANHOLE HAZARDS
HI! PLEASE TURN BACK AND REVIEW SECTION 4.4 ON PAGE 124

15. At the close manhole, a worker will have made the necessary preparations to enter the manhole safely. This will include the wearing of the safety harness, the venting of the manhole and the testing of the atmosphere. Worker topside at the close manhole wears a telephone headset (or uses a walkie talkie) for communications with the pull winch operator.

Many times the TV camera can be inserted in the sewer while the crew remains topside. The camera is placed on the skid assembly and lowered into the manhole using the pull cable. Also the camera is positioned using pull cables.



16. As soon as the worker is down the manhole and ready, the operator passes the TV camera assembly down to the worker for placement in the flow lines.
    a. If the pull winch cable was not attached above ground, it now must be connected to the front tow bridle of the camera. The worker must also check the connections on the power transmission cable, *CABLE STRAIN RELIEF*,[5] and the tag line winch.
    b. The worker then removes the lens cover from the camera and directs the pull winch operator to take in the slack cable.
    c. As the pull winch cable slack disappears, the worker guides the cable into the sewer line. The cable and camera are pulled from the manhole into the downstream sewer line to a point where the tips of the rear skids are even with the outer edge of the manhole. The worker then gives the command to the pull winch operator to stop!
    d. The camera is then turned on by the TV operator and all systems checked for proper operation. Be sure the *POWER IS OFF BEFORE* inspecting the connections, cables and TV camera. *NEVER* touch a TV camera in a manhole unless all power has been switched off. If any final adjustments are required, they are made at this time through a coordinated effort of the TV operator and the worker still in the manhole. The camera power is then turned off and the worker exits the manhole.
17. Once the assistant is out of the manhole, the operator returns to the operating station and opens necessary switches to power the camera and light. As soon as the picture and the lighting are satisfactory, the operator announces that all is ready.

---

[5] *Cable strain relief. A mesh type of device that grips the cable to prevent any strain on the power cable from reacing the connection to the camera and the light.*

18. When the operator indicates that all is ready, the pull winch operator and the assistant install necessary fair lead equipment in the two manholes and locate the winches over the manholes.
    a. As each operator completes the fair lead installation, they report their readiness to the TV operator.
    b. The operator is then cleared to tell the pull winch operator to pull away.

NOTE

FAIR LEAD EQUIPMENT IS NOT INSTALLED UNTIL THE OPERATOR HAS A SATISFACTORY PICTURE OF THE PIPELINE. IN SOME TYPES OF CAMERAS, AN IRIS OR F-STOP ADJUSTMENT MUST BE MADE TO THE CAMERA LENS AFTER INSIDE PIPE LIGHTING HAS BEEN TESTED. THIS SHOULD BE DONE BEFORE INSTALLATION OF FAIR LEAD EQUIPMENT AT THE UPSTREAM MANHOLE.

CAUTION

THE CAMERA MUST **NEVER** BE TOUCHED IN A MANHOLE **UNLESS ALL POWER HAS BEEN SWITCHED OFF.** SOME OLDER STYLE CAMERAS HAVE A CASE GROUNDING CIRCUIT WHICH COULD CAUSE EXTREMELY HIGH VOLTAGE IN THE CASE IN CERTAIN TYPES OF MALFUNCTIONS

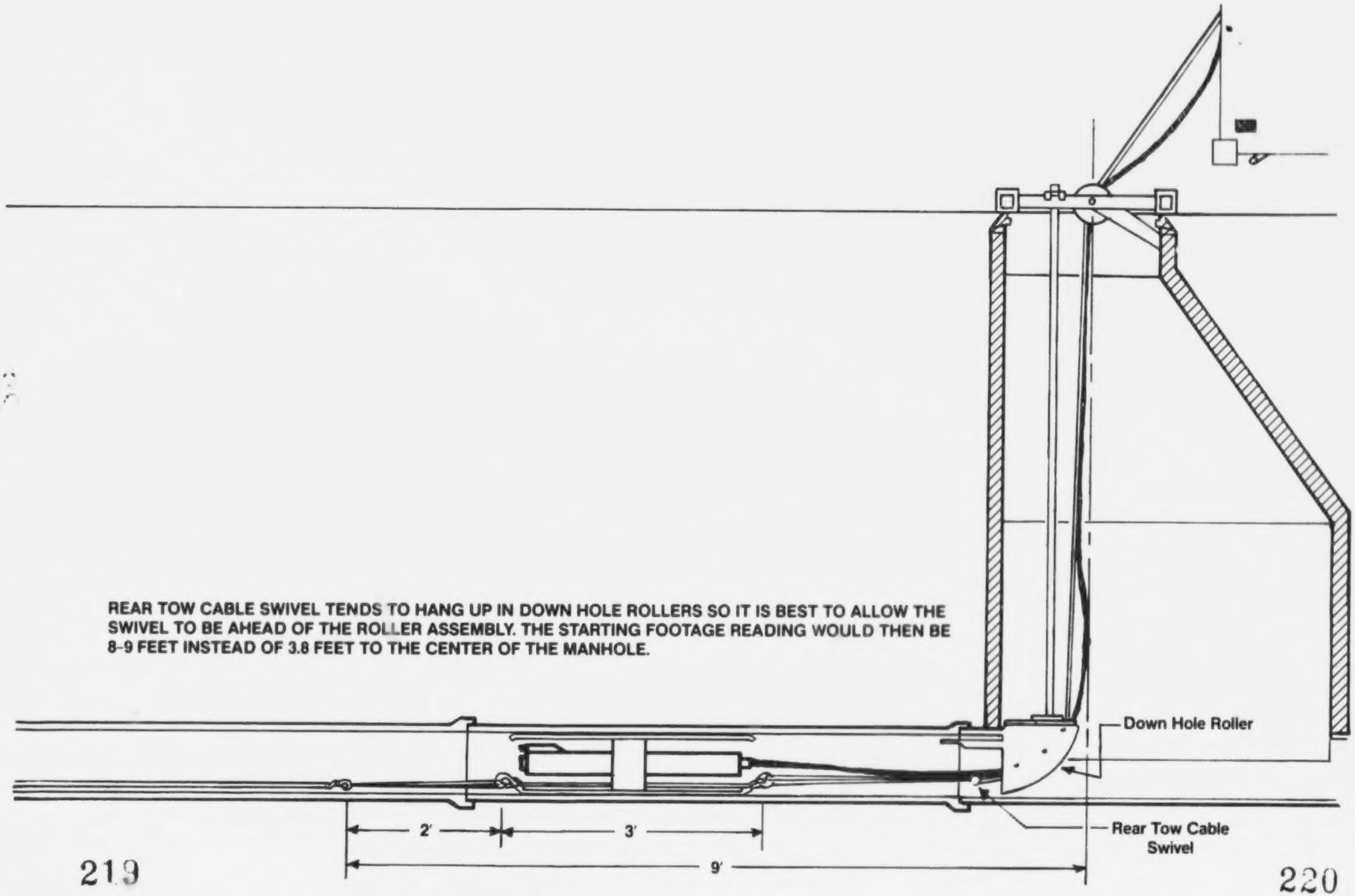
19. Slack in the power cable is pulled back through the footage meter and the footage meter set for proper reading. All footage readings must be estimated as closely as possible and should always start at the *CENTER* of the manhole so repair crews will always measure from the same point. Since the TV camera has been inserted into the sewer and is ready to move down the line. Since the TV camera has been inserted into the sewer and is ready to move down the line, the focal point is generally nine (9) feet from the center of the beginning manhole. The footage meter is set to read this number prior to beginning the inspection (Figure 5.8). This is extremely important so that all measurements are taken from the *center* of the starting (upstream) manhole.
20. When all is ready, the TV operator directs the operator at the pull winch to pull the camera. For directions, certain commands are agreed upon ahead of time. These can be determined to direct the proper operation of the winches. The following commands are provided only as suggestions:
    a. "GO AHEAD" from the operator at the TV monitor means for the camera to be winched through the sewer at regular speed. This speed in feet per second or minute will vary with the experience of the operator.
    b. "AHEAD SLOW" or "SLOWLY" means to reduce the speed of the camera's progress. This is generally done when some object is being approached and it may be desirable to stop for a polaroid photo or operation of the video recorder.
    c. "STOP" means exactly that. The pull winch operator stops pulling.
    d. "WE ARE GOING TO PULL BACK ______ FEET" means that the tag line winch is going to be used to pull the camera backwards. The pull winch operator must be advised of this action. The operator must remove the crank from the pull winch and shift the rachet (if the winch is so provided) to permit cable to be pulled backwards. Pulling back without letting the winch operator know can cause the crank to rotate rapidly, possibly striking the operator's hands or arms and causing pain or injury on certain types of equipment.

WE ARE GOING
TO
BACK
FI
FEET

    e. "WE ARE TAKING THE CAMERA BACK" means the camera is going to be pulled back out of the line.

CAUTION: WHENEVER PULLING A CAMERA BACK MORE THAN ONE FOOT, THE SLACK MUST BE TAKEN OUT OF THE POWER CABLE BY THE SERVICE WORKER STATIONED AT THE STARTING (UPSTREAM) MANHOLE WHILE THE CAMERA IS MOVING BACKWARDS. FAILURE TO DO THIS CAN PERMIT THE POWER CABLE TO BECOME TANGLED WITH THE CAMERA AND SKID ASSEMBLY AND CAUSE EXCESSIVE WEAR POINTS AND POSSIBLE SEVERE DAMAGE TO THE POWER CABLE ON CERTAIN TYPES OF EQUIPMENT.

21. There are two essential rules that must never be violated:
    a. While the camera is being moved through the line, the operator must never stop looking at the monitor picture. Any obstruction that could wedge or damage the camera or the light must be seen in time to stop the camera's forward progress. If the picture is lost for any reason, the forward progress of the camera must be stopped. If the picture cannot be reestablished again, the camera must be pulled backwards out of the line.
    b. If communications with the operator at the pull winch are lost, progress must be stopped immediately. For most crews, a shouted signal from one member indicates a loss of this communication.



REAR TOW CABLE SWIVEL TENDS TO HANG UP IN DOWN HOLE ROLLERS SO IT IS BEST TO ALLOW THE SWIVEL TO BE AHEAD OF THE ROLLER ASSEMBLY. THE STARTING FOOTAGE READING WOULD THEN BE 8-9 FEET INSTEAD OF 3.8 FEET TO THE CENTER OF THE MANHOLE.

Down Hole Roller
Rear Tow Cable Swivel
2′
3′
9′

Fig. 5.8 Adjustment of footage meter

22. If the pull winch operator begins to experience excessive drag on the cable, this fact must be immediately reported to the TV operator and the operation halted to check the cable guide devices ("downhole rollers") for wedging of the cable. Pull the camera back a few feet to see what could cause the drag or possible wedging. An out of round pipe can cause wedging. If a camera and skid assembly become locked or wedged in a pipe and the pull cables break, the sewer must be dug up to recover the camera. Therefore, it is very important that the TV operator and the worker operating the pull winch at the far (downstream) manhole develop an exact understanding of voice communications among themselves.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 236.

5.43A Why should the TV camera *ALWAYS* be pulled from the upstream to the downstream manhole?

5.43B What should a TV inspection crew do first when they arrive at a sewer to be inspected with a TV camera?

5.43C Is the TV pull winch located at the upstream or downstream manhole?

5.43D Why must the proper skids be used with the TV camera?

5.43E How is the pull winch cable kept from rubbing on the pipe at the downstream manhole?

5.43F Where in the pipe line should the footage meter be set to read zero?

5.43G What are two essential rules that must never be violated while the camera is moving through the line?

5.43H Why must extreme care be taken to prevent the TV camera from becoming wedged in the pipe?

5.432 Logging and Recording Television Inspections

A television inspection of a pipeline requires that all data are observed and recorded. The operator of the TV monitor must determine what is to be recorded, photographed, or video taped. As an operator you also should have the camera's progress halted every time you take your eyes off the monitor to record information.

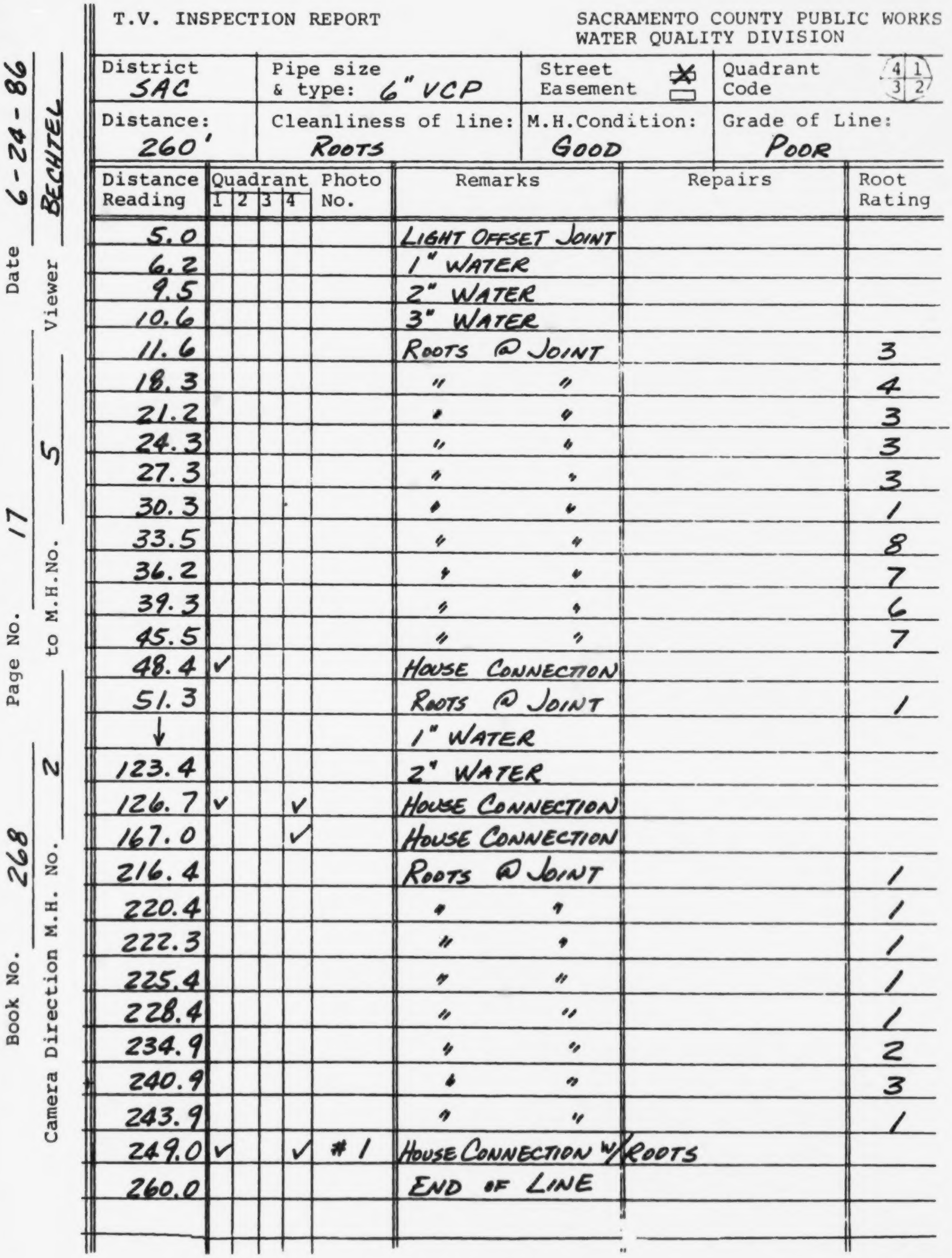
1. Most television inspection records are placed on a standard log (see example on Figure 5.9). Each operator may desire to slightly redesign a log sheet especially for their particular needs. However, there is certain basic information that should be included on sewer line television report forms. This information includes agency name, date, location, map number, TV operator's name, type of pipe and identification of section being televised (manhole numbers). Other information that could be helpful yet not critical include a sketch showing the direction of flow in the sewer line, the direction of the TV inspection, a north arrow, identification number of equipment being used, video tape identification number, "new work" or "in use" sewer designation, and name of inspector or concerned individual present. Coded initials and symbols or numbers are used for simplicity and to save time. Some of the suggested codes are:

   - SC Service connection. Quadrant number of position of entry is usually added. Some operators use a time clock notation rather than a quadrant number. (See Figure 5.9, sample log.)
   - R Roots. Generally followed by number indicating growth. (See Figure 5.10, root rating chart.)
   - I Infiltration. May be followed by number to indicate estimated gallons per minute and a quadrant number to show point of entry. To learn how to estimate infiltration flows, if possible, observe typical flows at locations or in a lab where actual flows can be measured. By comparing estimated flows with actual flows, accurate flow estimates can be made by experienced operators in the field.
   - DL-G Dirty Line, grease or soap cake. For sand or silt deposits DL-S, for rocks DL-K.
   - C/B Cracked or broken place. This can have a remark indicating possible collapse of the pipe for extensive damage of this type.
   - OJ Offset joint. Can be followed by a number or fraction to indicate inches or fractions of an inch out of line.
   - GDS Grade defect, starting point.
   - GDE Grade defect, ending point.
   - CUW Camera under water. Point where lens was more than half covered by water.
   - COW Camera out of water. Point where lens was less than half covered by water.

See the appendix at the end of this chapter for a three-letter coding system for sewer inspection, defects and actions/responses (Section 5.10).

   Combinations of these are used to provide information about one location. Example: 263 SC-1-R2-I5 = "Station 263, Service Connection from Quadrant One, Roots to rating two, infiltration at approximately five gallons per minute, all from service lateral."

2. Polaroid still photographs, black and white, are often used to support log entries. Infiltration points, bad offsets, damaged laterals, root growths, and broken pipe locations are examples. When each photo is taken, the footage and log entry are recorded on the back of the photo (where a video-footage readout system (Fig. 5.6) is not provided or used) (Figures 5.11 and 5.12).
   a. Polaroid cameras have an automatic exposure device that automatically makes a good picture from the light in the television monitor. There must be a minimum of other light sources that can affect the camera's light adjustment process. In some situations, a special hood may be necessary to eliminate other light sources. This hood must permit the front face of the camera, as well as the electric eye port, to be exposed to the monitor picture.



T.V. INSPECTION REPORT

SACRAMENTO COUNTY PUBLIC WORKS
WATER QUALITY DIVISION

Date 6-24-86
Viewer BECHTEL
Page No. 17
to M.H.No. 5
Book No. 268
Camera Direction M.H. No. 2

District SAC	Pipe size & type: 6" VCP	Street ☒ Easement ☐	Quadrant Code 4 1 / 3 2
Distance: 260'	Cleanliness of line: ROOTS	M.H.Condition: GOOD	Grade of Line: POOR

Distance Reading	Quadrant				Photo No.	Remarks	Repairs	Root Rating
	1	2	3	4				
5.0						LIGHT OFFSET JOINT		
6.2						1" WATER		
9.5						2" WATER		
10.6						3" WATER		
11.6						ROOTS @ JOINT		3
18.3						" "		4
21.2						" "		3
24.3						" "		3
27.3						" "		3
30.3						" "		1
33.5						" "		8
36.2						" "		7
39.3						" "		6
45.5						" "		7
48.4	✓					HOUSE CONNECTION		
51.3						ROOTS @ JOINT		1
↓						1" WATER		
123.4						2" WATER		
126.7	✓			✓		HOUSE CONNECTION		
167.0				✓		HOUSE CONNECTION		
216.4						ROOTS @ JOINT		1
220.4						" "		1
222.3						" "		1
225.4						" "		1
228.4						" "		1
234.9						" "		2
240.9						" "		3
243.9						" "		1
249.0	✓			✓	#1	HOUSE CONNECTION W/ROOTS		
260.0						END OF LINE		

Fig. 5.9 TV inspection report

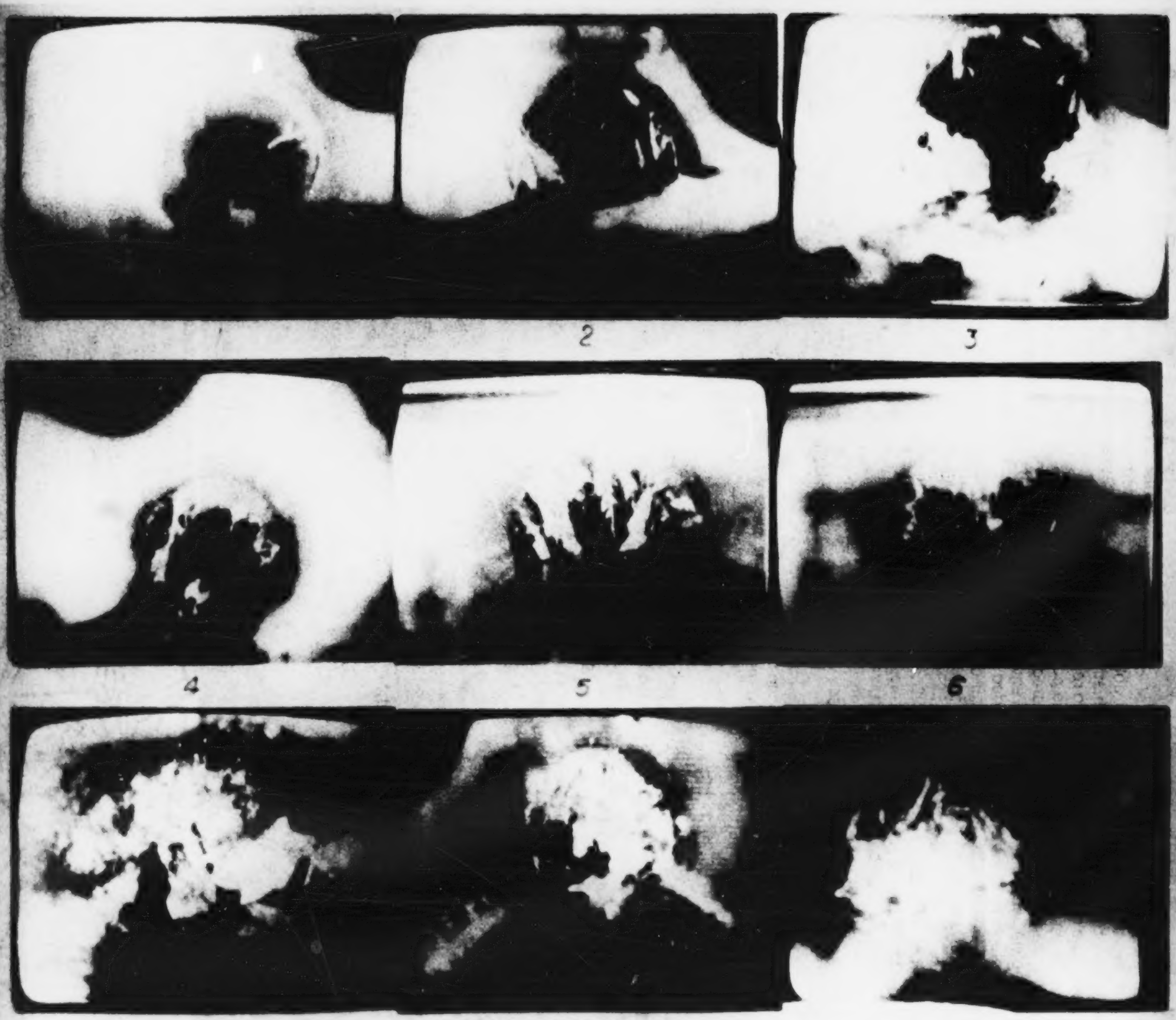


Fig. 5.10 Root rating system
(Courtesy of Sacramento County, Division of Water Quality)

b. To be effective for focus, a polaroid camera must have a close-up lens and sighting kit.

c. Bright lighting behind a polaroid camera can cause reflections in the glass face of the monitor. Adequate curtains or shrouding should be provided to block out background light.

3. Video tape recordings can be used in place of or in addition to a polaroid camera. Video tapes are able to provide a better record of some types of pipe situations. While most video tape recorders have the ability to record the voice of the TV operator when describing the condition of the sewer, defects observed, and the footage of the situation being viewed, voice records are not required when a video footage readout system is provided and used. Video footage readout systems are helpful, but a TV operator's actual description and comments are very useful when replaying the video tape in an office for someone who is not very familiar with the conditions in the collection system. These systems cannot replace the expertise of an experienced operator who can accurately describe the condition of the pipe in the audio portion of the video tape. In addition, when background noises such as autombile traffic, industrial areas and airport traffic areas, make it impossible to use the audio at the time of the actual inspection, the TV operator can replay the tape later at a more quiet site and "dub" in the voice comments at that time.

Another feature usually provided with video recording equipment is a selector switch. This three position switch permits televising without recording, televising and recording at the same time, and instant replay of recorded tape after tape rewind. If the operator sees an object or situation to be video taped, the operator starts the recorder, talks into the microphone to describe the situation, footages or other remarks, and then stops the television camera progress after the TV camera has passed the problem area. The operator may then rewind the video tape to the place it was when the recording was started, switch to "VIR" (Video Instant Replay) and replay the recording in the monitor to make certain the record and words desired are correct. The operator can then switch back to televise, switch off the recorder and proceed on down the pipe.

Some of the advantages of a video recording system are:

a. The system records motion while still photography freezes motion. In an infiltration situation, the ability to record water flow in action for later viewing has definite advantages.

b. Where a pipe is off-grade, starting the video recording operating during the full passage is desirable. When the supervisor reviews the tape, the supervisor can determine the seriousness of the situation and the necessary corrective action. If a video footage readout system is used, footages are automatically recorded on the tape. When no video footage readout system is provided, the operator should call out footages at frequent and regular intervals into the audio recording system of the tape recorder.

NOTE: IN COLLECTION SYSTEMS WITH DIPS OR SAGS WHERE WATER IS ALLOWED TO STAND, SOLIDS CAN SETTLE OUT AND CREATE A DANGEROUS NUISANCE BY PRODUCING HYDROGEN SULFIDE AS WELL AS BY CAUSING HIGH MAINTENANCE COSTS. VIDEO TAPE DOCUMENTATION OF THE EXTENT AND SEVERITY OF THESE LOCATIONS WILL PROVIDE THE NECESSARY INFORMATION SO ECONOMICAL AND QUICK REPAIR OR CORRECTION OF THE SITUATION CAN BE MADE.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 237.

5.43I Why should the TV camera be stopped while the operator records data?

5.43J What items are photographed with a polaroid camera?

5.43K What are some of the advantages of using a video tape over a polaroid camera?

5.433 TV Log Sheet Explanation

Different agencies use different approaches to logging TV inspection data. This section illustrates the procedures used by the City of Phoenix.

TV Inspection Report (Figure 5.A) shows the TV log as made out by the TV operator.

Explanation:

Flow direction arrows and TV direction arrows are drawn in as they occur in that specific run.

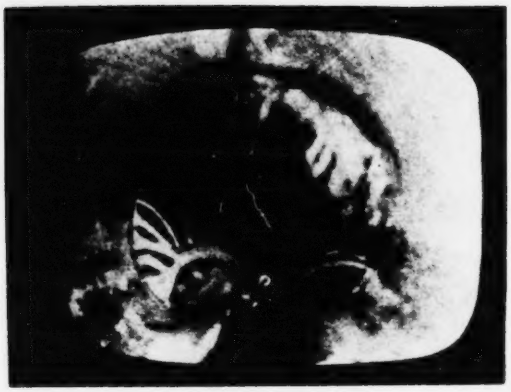
Run is ✓'d as "routine," "complaint" or "new work."

Starting manhole is placed in diagram on the left and ending manhole on the right with actual length of line recorded in center (432 LF).

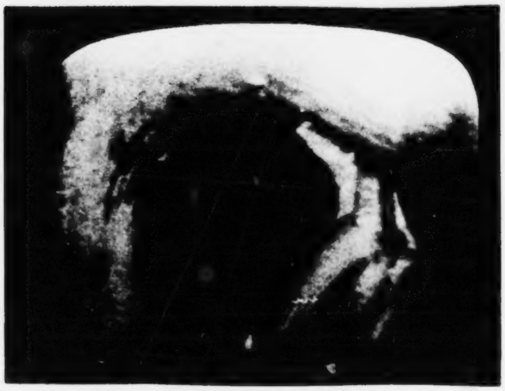
Starting stationing is always recorded as #0+00 (center of manhole) in the beginning manhole.

"TN FACT" or "TN TAP" distinguishes between a factory or field tapped service connection into the main.

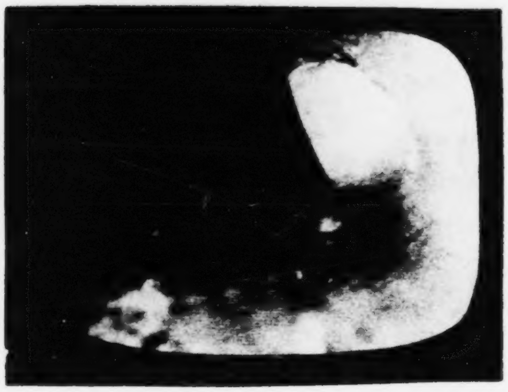
City of Phenix does not use "quadrant code" - a "severity code" of 1-10 is used, i.e. 3 , 6 , 9 ; this relates to the severity of the condition stated, i.e.; "roots @ joint 5 ." This indicates that the root intrusion is obstructing approximately 1/2 of the diameter of the pipe. In addition, "pipe cracked 9 " would indicate a severely cracked pipe, very near collapse.



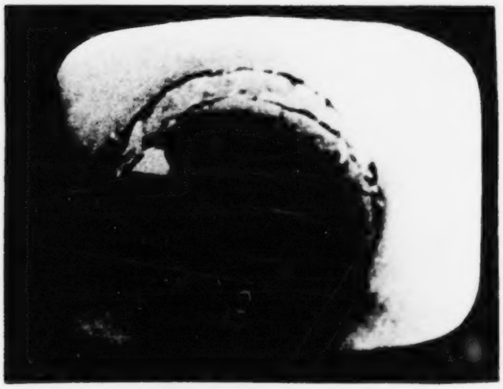
Infiltration at defective pipe joint.



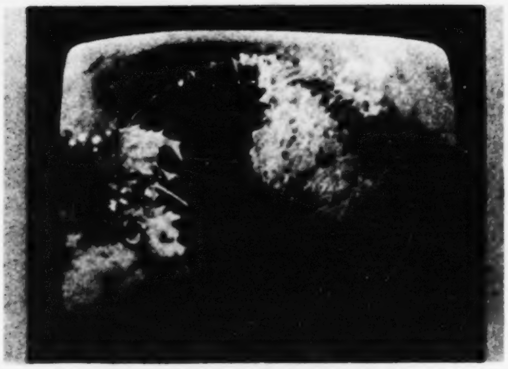
Infiltration or inflow at
defective service connection.



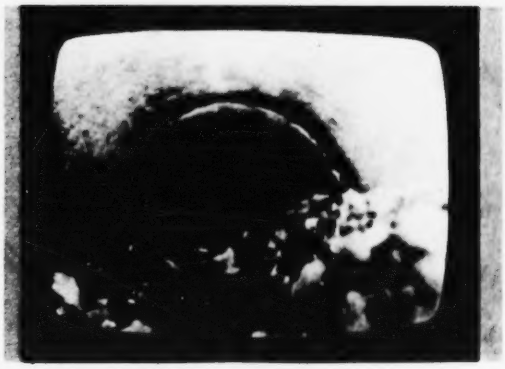
Protruding service tap.



Drop joint.

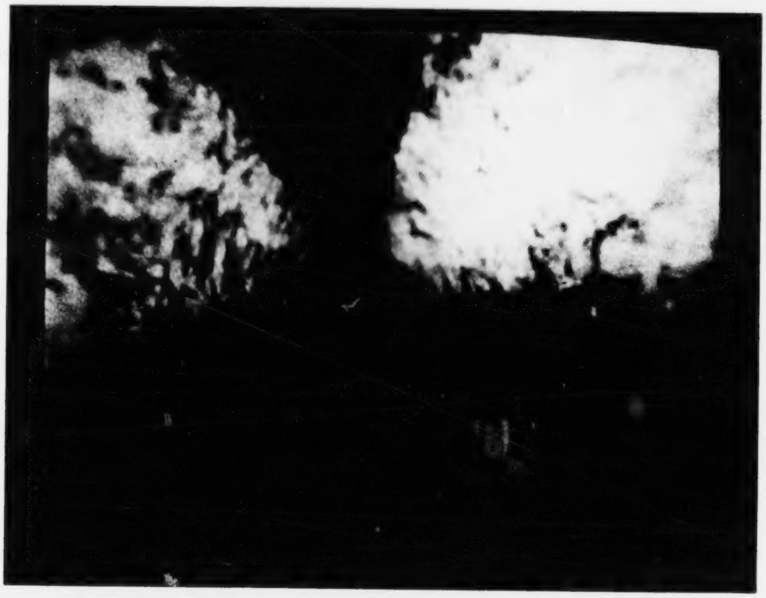


Root intrusion.



Dirty line, gravel and debris.

Fig. 5.11 Typical data available from CCTV sewer inspections



Heavy grease

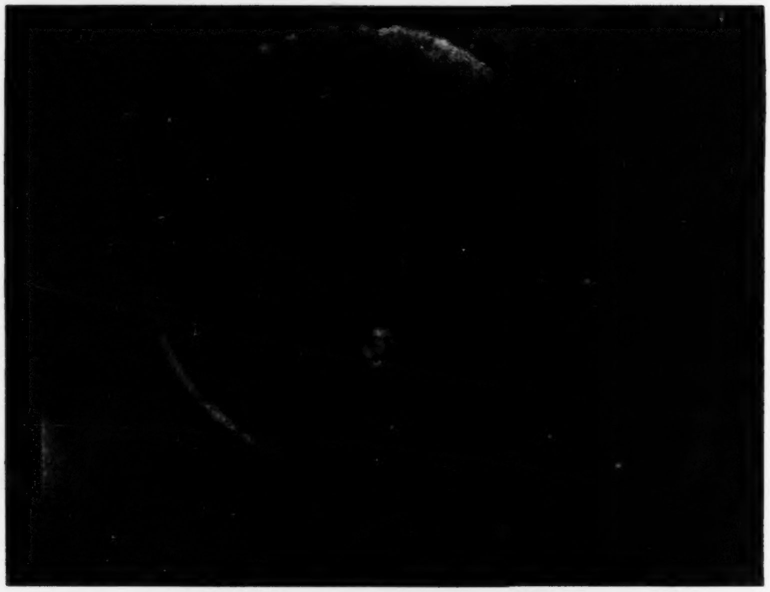
Grease build-up

Fig. 5.11 Typical data available from CCTV sewer inspections (con't.)

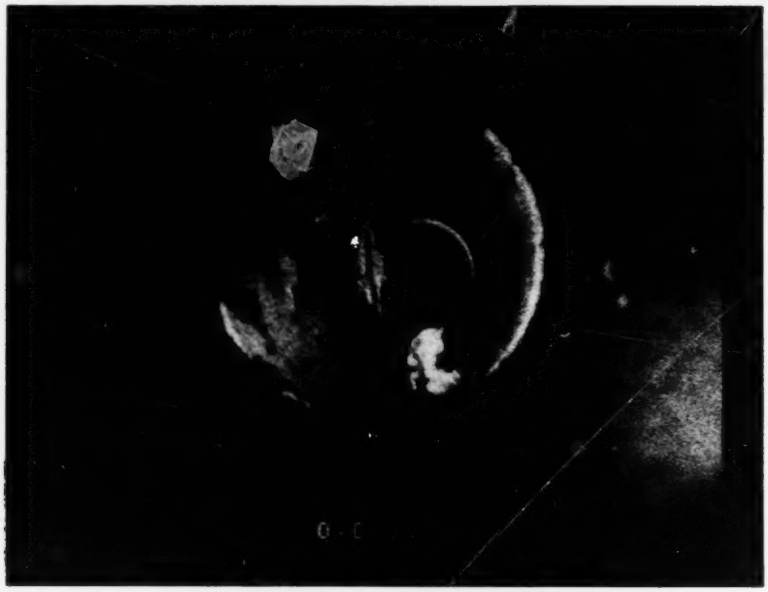
Protruding tap

Detergent build-up

Fig. 5.11 Typical data available from CCTV sewer inspections (con't.)



Roots in PVC pipe



Root intrusion

Fig. 5.11 Typical data available from CCTV sewer inspections (con't.)

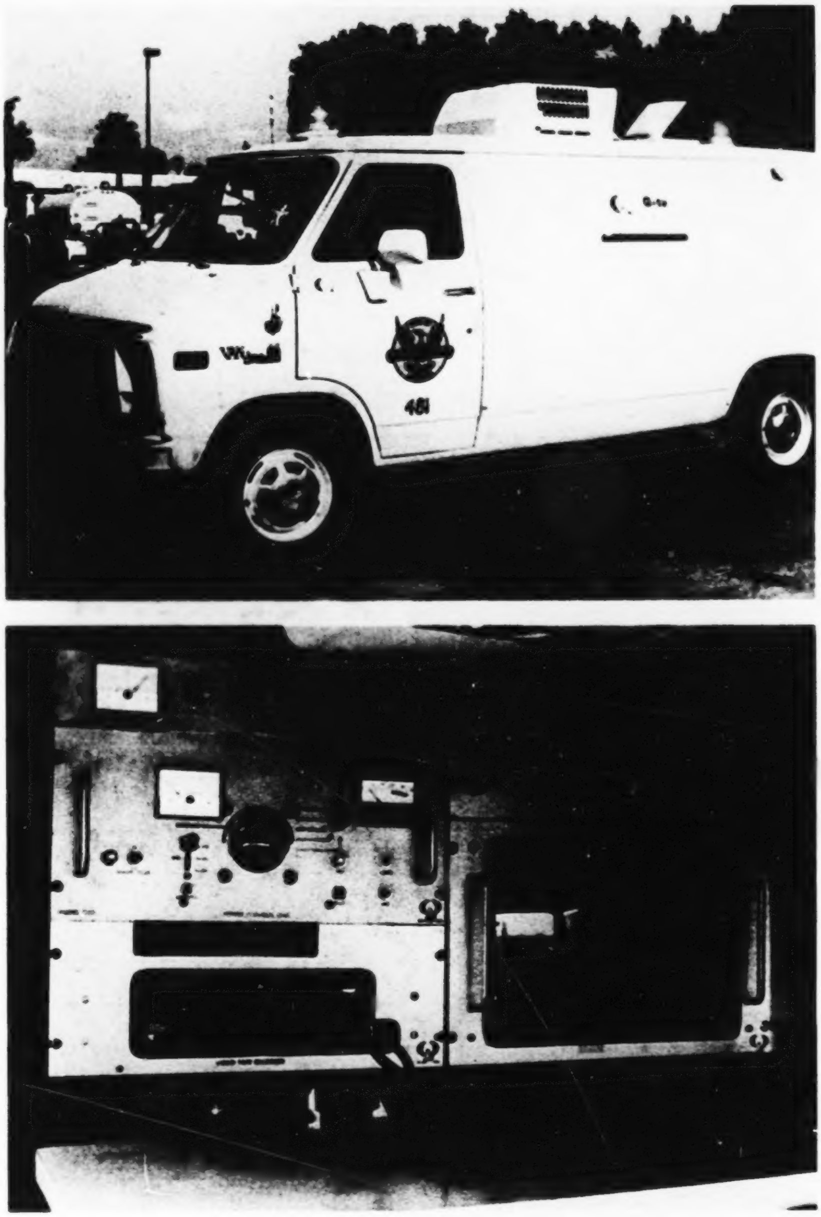
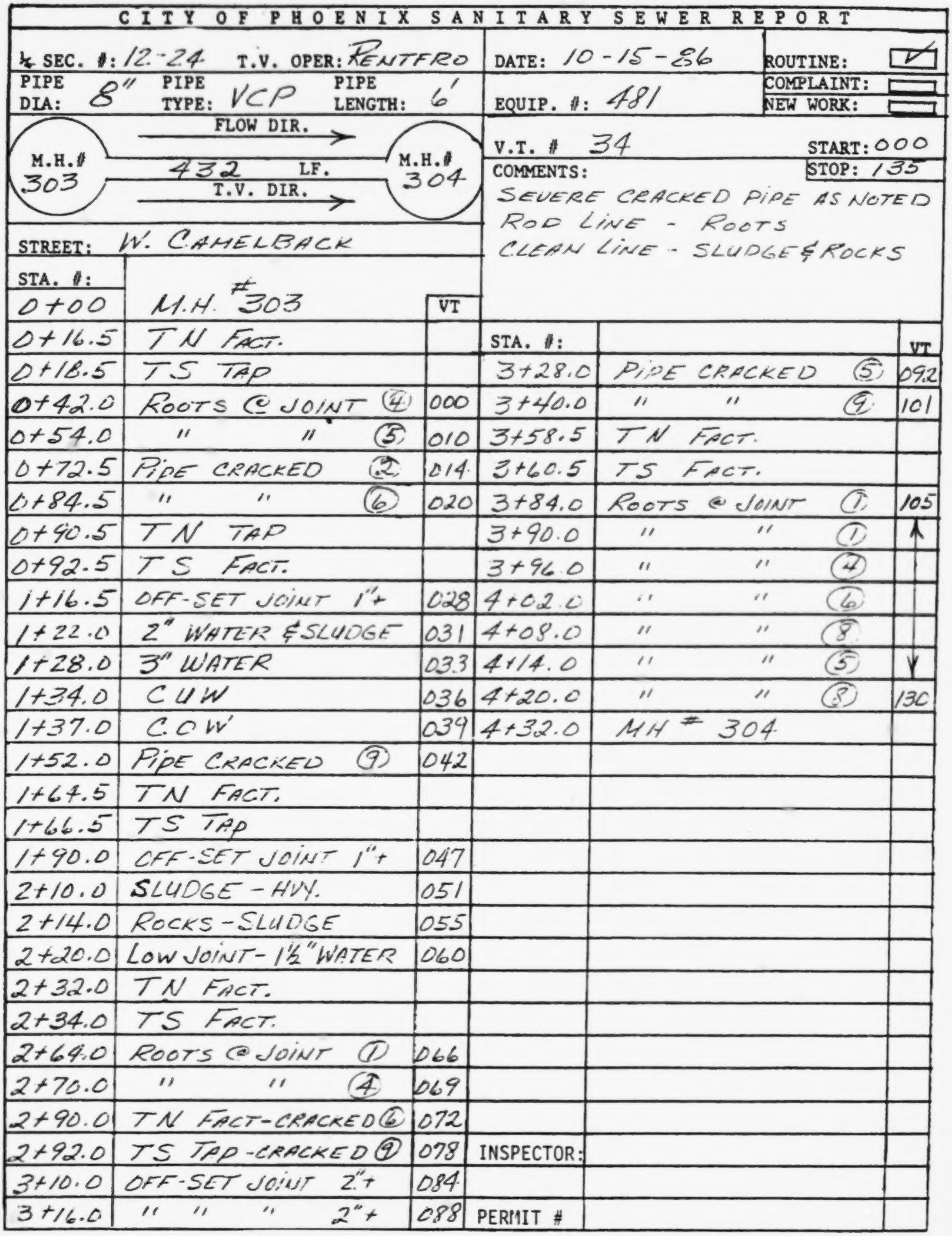


Fig. 5.12 CCTV system van and operator's station



CITY OF PHOENIX SANITARY SEWER REPORT

¼ SEC. #: 12-24 T.V. OPER: RENTFRO

DATE: 10-15-86

ROUTINE: ☑

COMPLAINT: ☐

NEW WORK: ☐

PIPE DIA: 8" PIPE TYPE: VCP PIPE LENGTH: 6'

EQUIP. #: 481

M.H.# 303 — 432 LF. — M.H.# 304

FLOW DIR.
T.V. DIR.

V.T. # 34

START: 000

STOP: 135

COMMENTS:

SEVERE CRACKED PIPE AS NOTED

ROD LINE - ROOTS

CLEAN LINE - SLUDGE & ROCKS

STREET: W. CAMELBACK

STA. #:		VT
0+00	M.H. #303	
0+16.5	TN FACT.	
0+18.5	TS TAP	
0+42.0	ROOTS @ JOINT ④	000
0+54.0	" " ⑤	010
0+72.5	PIPE CRACKED ②	014
0+84.5	" " ⑥	020
0+90.5	TN TAP	
0+92.5	TS FACT.	
1+16.5	OFF-SET JOINT 1"+	028
1+22.0	2" WATER & SLUDGE	031
1+28.0	3" WATER	033
1+34.0	CUW	036
1+37.0	COW	039
1+52.0	PIPE CRACKED ⑨	042
1+64.5	TN FACT.	
1+66.5	TS TAP	
1+90.0	OFF-SET JOINT 1"+	047
2+10.0	SLUDGE - HVY.	051
2+14.0	ROCKS - SLUDGE	055
2+20.0	LOW JOINT - 1½" WATER	060
2+32.0	TN FACT.	
2+34.0	TS FACT.	
2+64.0	ROOTS @ JOINT ①	066
2+70.0	" " ④	069
2+90.0	TN FACT - CRACKED ⑥	072
2+92.0	TS TAP - CRACKED ⑨	078
3+10.0	OFF-SET JOINT 2"+	084
3+16.0	" " " 2"+	088

STA. #:		VT
3+28.0	PIPE CRACKED ⑤	092
3+40.0	" " ⑨	101
3+58.5	TN FACT.	
3+60.5	TS FACT.	
3+84.0	ROOTS @ JOINT ①	105
3+90.0	" " ①	
3+96.0	" " ④	
4+02.0	" " ⑥	
4+08.0	" " ⑧	
4+14.0	" " ⑤	
4+20.0	" " ⑧	130
4+32.0	MH # 304	

INSPECTOR:

PERMIT #

145-191D
Rev. 4/85

Fig. 5.A TV inspection report. Also see reviewed TV inspection report (Figure 5.B)

The columns headed by "VT" indicate the minute reading on the video tape where the identified defect can be viewed. This is very helpful because it allows a supervisor to "fast forward" to a particular location to quickly evaluate and establish repair priorities.

Explanation:

This illustrates the addition of the "service request" stamp placed there by the person in authority to indicate that the TV log has been reviewed and recommended the action shown on the request. In the illustrated form (Figure 5.B), the service request calls for three activities:

1. Construction crew to make needed repairs,
2. Rodding crew to power rod entire line to remove roots, and
3. Cleaning (high velocity cleaner) crew to remove sludge and debris.

Appropriate follow up paperwork is then activated and forwarded to the proper crew. Response reporting is encouraged through the form's design (see SEWER CLEANING REPORT and MANHOLE ADJUSTMENT REPORT for forms activated by TV inspection report).

TV crews should realize that it is only necessary to video tape *DEFECTS* in active sewer lines. Taping the entire pipe run, unless it is for a specific presentation or purpose, would become quite costly and soon create tape storage problems for most agencies. On the other hand, taping the entire pipe run when inspecting sewer lines for acceptance of a new project is highly recommended. A comparison tape can then be made several months later into the contractor's guarantee period to check for slower developing faults that could seriously affect the long-term performance of a sewer line.

5.434 Special Precautions in Televising Collection Systems

Certain types of conditions encountered when televising sewers require special precautions. The operator and the crew should brief each other on the procedures to follow in the event these situations are encountered and there is a risk of damage or wedging of the camera in the sewer.

1. Offset joints restrict the pipe diameter and can cause a camera to wedge tightly in place rather than pass through. Two different types of common offsets require two different procedures.

   a. A horizontal offset is where the joint section is shown to be out of alignment to the right or left. As an operator gains experience in reading the severity of these offsets, the operator will know if the camera assembly can pass these or not. Where there is doubt, the TV operator will advise the operator at the pull winch, usually with a simple two word announcement, "RIGHT OFFSET," or "LEFT OFFSET." The pull winch operator will then apply only enough pressure on the winch crank handle to move the camera slowly ahead. If you find a sudden resistance to the progress of the camera, YOU MUST NOT ATTEMPT TO INCREASE FULL PULLING POWER ON THE CAMERA ASSEMBLY.

   Attempting to force the camera past such an obstruction can cause it to be wedged so tightly that the tag line winch cannot pull the camera back out the sewer. When the pull winch operator finds that moderate pressure on the winch crank cannot move the camera ahead, the operator should announce, "WE ARE HUNG UP." The footage should then be recorded on the TV log with the appropriate explanation such as "TV camera would not pass." The camera should then be pulled back out of the line with the tag line winch. The bad offset should be repaired before another attempt is made to televise that run of pipe.

   b. Two types of vertical offsets may be encountered and each requires a different procedure. A 'DROP JOINT' is where the camera must drop down to get into the next section of pipe. A 'JUMP JOINT' is where the camera has to be lifted up in order to get into the next section of pipe. (See Figure 5.13).

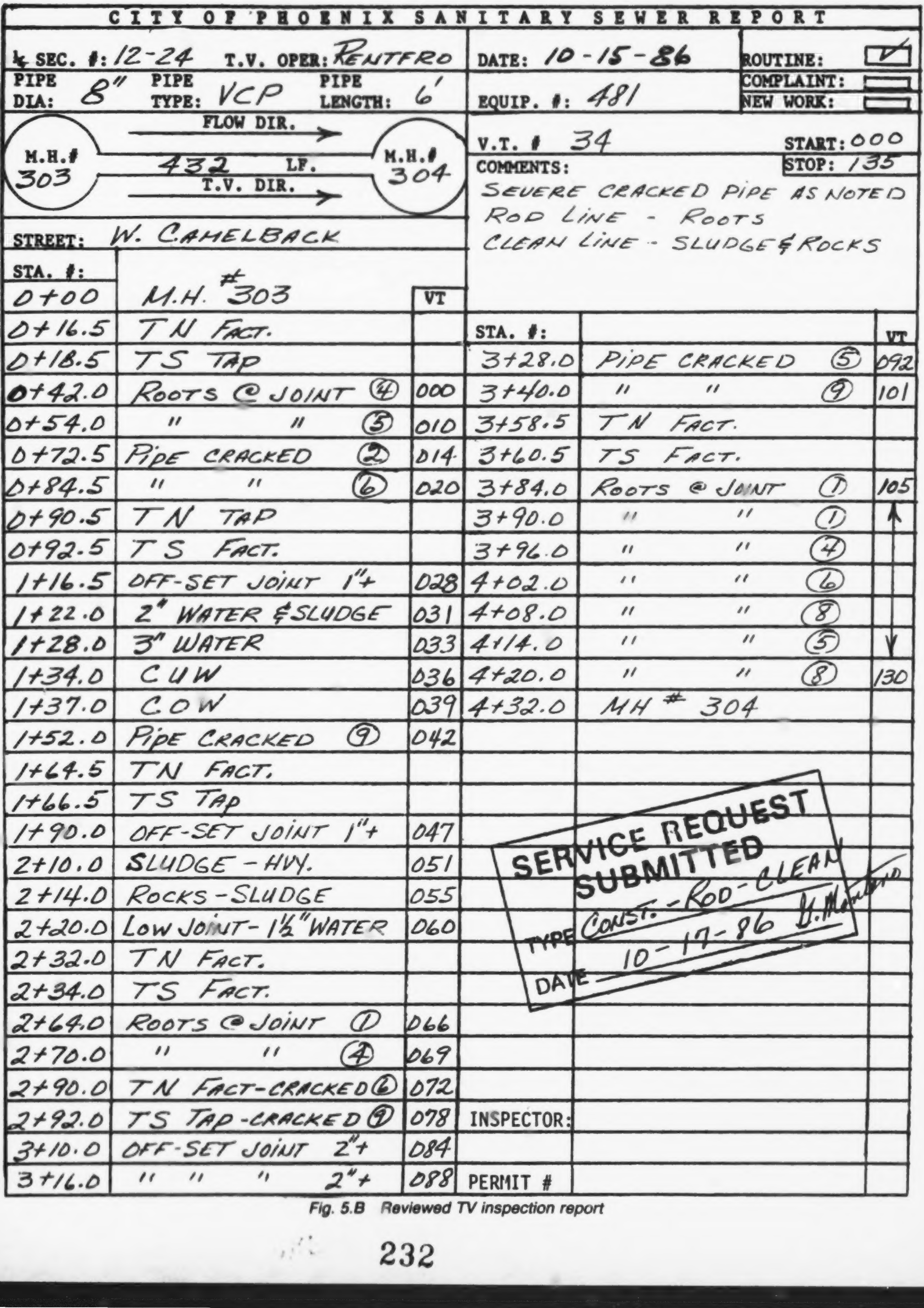
      1) Where the TV operator sees a drop joint ahead, the pull winch operator is warned. The camera progress is reduced to an extremely slow speed. In most cases, and with a little experience, a TV operator can determine if the joint can be passed without damage or wedging several inches ahead of the camera. If there is any doubt, the attempt to pass a drop joint should not be made. If the pull winch operator feels the camera come to a sudden stop, the operator should not attempt to pull it farther.

      As with a tight horizontal offset, the footage must be recorded on the log, and the camera should be pulled back out of the line and the pipe joint repaired before televising that run again. In addition to possible damage to the camera in passing such a joint, or attempting to, the ability to pull the camera back out may be lost after the joint is passed. Should a point farther down the pipe prevent any more forward progress, the camera will have to be pulled back out with the tag line winch and a drop joint will become a jump joint. If the camera becomes wedged tight in the pipe, excavation to recover the camera will be necessary.

      2) Where the TV operator sees a jump joint ahead, the pull winch operator must be warned. The camera may be moved without danger until the lower skids butt into the ledge and progress comes to a halt. The TV operator must decide whether to try to 'jump' the camera or pull it back out. The extent or severity of the offset is the factor to be evaluated. To 'jump' the camera assembly, the pull winch operator takes fairly heavy tug or pull on the winch cable and holds it. The tag line winch or TV cable is then given a short pull back and released. In effect, the camera and skid assembly are more or less given a heavy jerk. The objective is to pull the lower skids out of contact with the ledge just far enough to allow the pull cable to 'lift them' over the ledge. This procedure may have to be tried several times.

      In general, any jump joint that can be negotiated in the above manner can be pulled back through without problem in the event the camera has to be backed out of the line.

2. When the camera goes under water to a point where the top half of the pipe cannot be clearly seen, the operator is no longer able to see obstructions or offset joints adequately to prevent wedging or damage. The TV operator



CITY OF PHOENIX SANITARY SEWER REPORT

¼ SEC. #: 12-24 T.V. OPER: RENTFRO

DATE: 10-15-86

ROUTINE: ☑
COMPLAINT: ☐
NEW WORK: ☐

PIPE DIA: 8" PIPE TYPE: VCP PIPE LENGTH: 6'

EQUIP. #: 481

M.H.# 303 — FLOW DIR. → 432 LF. T.V. DIR. → — M.H.# 304

V.T. # 34 START: 000 STOP: 135

COMMENTS:
SEVERE CRACKED PIPE AS NOTED
ROD LINE - ROOTS
CLEAN LINE - SLUDGE & ROCKS

STREET: W. CAMELBACK

STA. #:		VT
0+00	M.H. #303	
0+16.5	TN FACT.	
0+18.5	TS TAP	
0+42.0	ROOTS @ JOINT ④	000
0+54.0	" " ⑤	010
0+72.5	PIPE CRACKED ②	014
0+84.5	" " ⑥	020
0+90.5	TN TAP	
0+92.5	TS FACT.	
1+16.5	OFF-SET JOINT 1"+	028
1+22.0	2" WATER & SLUDGE	031
1+28.0	3" WATER	033
1+34.0	CUW	036
1+37.0	COW	039
1+52.0	PIPE CRACKED ⑨	042
1+64.5	TN FACT.	
1+66.5	TS TAP	
1+90.0	OFF-SET JOINT 1"+	047
2+10.0	SLUDGE - HVY.	051
2+14.0	ROCKS - SLUDGE	055
2+20.0	LOW JOINT - 1½" WATER	060
2+32.0	TN FACT.	
2+34.0	TS FACT.	
2+64.0	ROOTS @ JOINT ①	066
2+70.0	" " ④	069
2+90.0	TN FACT - CRACKED ⑥	072
2+92.0	TS TAP - CRACKED ⑨	078
3+10.0	OFF-SET JOINT 2"+	084
3+16.0	" " " 2"+	088

STA. #:		VT
3+28.0	PIPE CRACKED ⑤	092
3+40.0	" " ⑨	101
3+58.5	TN FACT.	
3+60.5	TS FACT.	
3+84.0	ROOTS @ JOINT ①	105
3+90.0	" " ①	↑
3+96.0	" " ④	
4+02.0	" " ⑥	
4+08.0	" " ⑧	
4+14.0	" " ⑤	↓
4+20.0	" " ⑧	130
4+32.0	MH # 304	

SERVICE REQUEST SUBMITTED
TYPE CONST. - ROD - CLEAN
DATE 10-17-86

INSPECTOR:

PERMIT #

Fig. 5.B Reviewed TV inspection report

SEWER CLEANING REPORT

CLEANING NEEDED DATE: ____________

FOREMAN: ____________ ¼ SEC. # ________ M.H. # ______ TO M.H. # ________

SIZE OF LINE: __________ TYPE OF MATERIAL IN LINE: ____________ CLEANING NEEDED WITHIN __________ DAYS

HYDRANT LOCATION: ______________________________

COMMENTS:

SEWER CLEANING COMPLETED

FOREMAN: ______________________________ DATE: ____________

¼ SEC. # __________ M.H. # __________ TO M.H. # ________ AMOUNT OF MATERIAL: __________

FEET JETTED: __________ FEET RODDED: __________ FEET BUCKETED: __________

COMMENTS:

MANHOLE ADJUSTMENT REPORT

FOREMAN: ______________ ¼ SEC. # ________ M.H.# ______ DATE: ____________

MH TO BE RAISED: ______ INCHES MH TO BE LOWED: ______ INCHES

REFORM CHANNEL: __________ STEPS TO BE REPLACED: ________ TYPE PAVEMENT: ________

REMARKS:

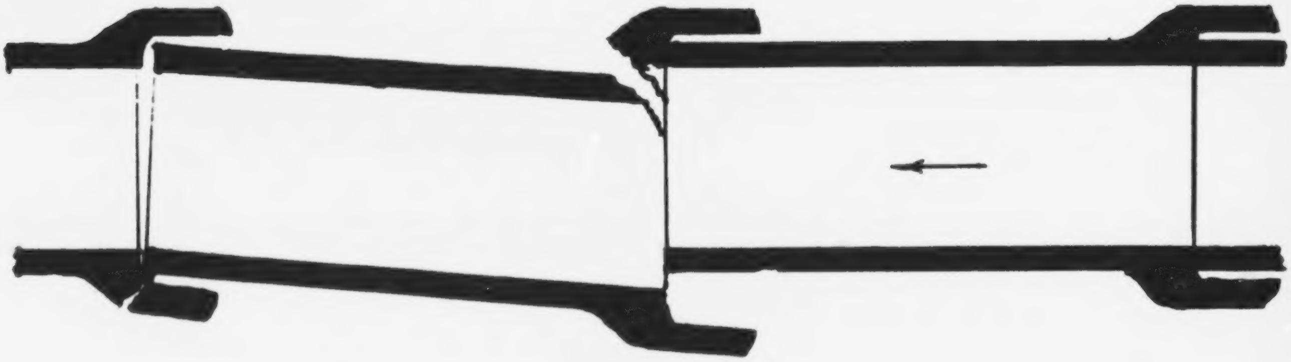
MANHOLE ADJUSTMENT COMPLETED

FOREMAN: ______________________________ DATE: ____________

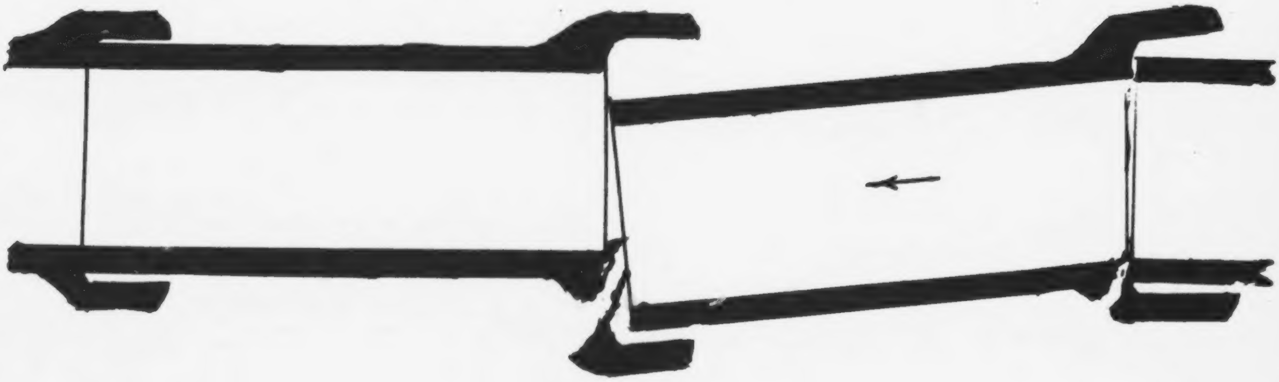
MH RAISED: ________ INCHES MH LOWERED: ________ INCHES

CHANNELS REFORMED: ________ STEPS REPLACED: __________ PAVEMENT REPLACED: ______

DROP JOINT:
Pulling television camera from right to left past this joint will cause it to 'drop.'



JUMP JOINT:
Television camera must be 'jumped' from right to left to pass this type of situation.



Pulling the camera past situations like these can prevent the camera from being pulled back out if a full obstruction is encountered later down the pipe. It is best to document conditions like these, repair them and then re-televise the line.

Fig. 5.13 Drop joint and jump joint

should advise the pull winch operator of the circumstances by announcing "CAMERA UNDER WATER, TAKE IT SLOW AND EASY." If the pull winch operator finds the camera has stopped and cannot be moved with very moderate pressure on the winch handle, the winch operator should advise the TV operator. To be safe, back the camera out of the sewer and have the sewer repaired at that point before trying to pull the camera through.

If the submerged section of the sewer must be inspected, carefully assess the precautions necessary with respect to plugging the line for any length of time. Flow-bypass pumping and working during low flow times must be considered in high volume lines to avoid the possibility of incurring property damage from wastewater backing up into residences and businesses. One method of televising through low spots or sags in the line is to use a high velocity cleaner with closed end nozzle to clean directly ahead of the TV camera. The jet of water from the nozzle will push the water clear of the pipe for a short distance. When the TV picture becomes submerged again, stop the high velocity cleaner and allow the water to flow out the pipe. Start the high velocity cleaner again and repeat until the submerged section has been inspected.

3. When coming out of a situation where the camera has been under water, it is possible for the viewport to become fouled with grease or other surface debris. In most cases the decrease in visibility will be negligible, but it is possible to have a foggy or indistinct picture which can reduce the visual inspection effectiveness. There are several things that can be attempted to clear the viewport.

   a. If the distance to the downstream manhole is more than fifty or a hundred feet, back the camera up until it is fully under water again. Allow the camera to stand for perhaps a minute to allow any debris on the viewport to be floated off, then pull it forward rapidly to the point where the viewport is once again out of the water. The idea behind this is to create a wave ahead of the viewport that washes surface debris aside with water brought up with the camera. This may be attempted safely several times. Do not pull the camera forward farther than its former progress.

   b. If the distrance to the downstream manhole is still over fifty or a hundred feet, open a fire hydrant or similar source of a large volume of water and discharge into the upstream manhole (any upstream manhole) in an attempt to wash the surface debris through the line. Pull the camera back into the water to rinse the viewport and proceed once it is clear.

   c. If the downstream manhole is not too far, pull the camera down to it in the same manner as if it were underwater. This means the pull winch operator moves it slowly, advising of any sudden stoppage of progress. Once at the downstream manhole, clean the viewport and pull it back to the place where it came out of the water and proceed to televise the rest of the pipe.

   d. If the lens becomes foggy or the sewer is full of steam from the discharge of warm waters (from laundries for example), the warm flows can be cooled by discharging flow from a fire hydrant into the sewer.

4. Other obstructions are handled in much the same manner. Such problems as protruding service connections (protruding taps), objects sticking into a pipe, pieces of broken pipe protruding into the pipe, and heavy root developments are typical examples. Once again, teamwork between the crew members will determine if these can be passed without damage to the equipment or if they must be removed before televising the remainder of the line. A rule of common sense is applicable at this point.

A
RULE
OF
COM
SENSE

RULE: IF A SITUATION IN A PIPE PRESENTS A RISK TO THE CAMERA AND THE TELEVISING EQUIPMENT, IT IS OBVIOUSLY A SITUATION WHICH REQUIRES EXCAVATION AND REPAIR. UP TO THAT POINT, THE CAMERA HAS DONE ITS JOB AND IT CAN BE PULLED BACK OUT AND USED IN OTHER LOCATIONS WHILE THE NECESSARY REPAIRS ARE BEING MADE TO THE PIPELINE. TO RISK DAMAGE AND THE NEED TO REPAIR THE CAMERA CAN PRODUCE UNNECESSARY COSTS. THIS RISK ALSO CAN PREVENT THE USE OF THE TELEVISION EQUIPMENT WHILE CAMERA REPAIRS ARE BEING MADE.

5. Camera tumbled or off-vertical conditions should not be a problem. A properly designed camera and skid assembly should right itself in a straight pipe run. Even if a camera is inverted and the picture is up-side-down, moving the camera back and forth should cause it to return to the upright position.

   a. Bends and some types of offset joints in a pipe can cause a camera to get tilted. This is usually a temporary condition.

   b. If a camera does not right itself in a few feet, it is an indication that something is wrong. A cable could be tangled in the skid assembly, or a root clump has fouled the assembly. Under such circumstances, the operator should select the most rapid and safest method of getting the camera out of the line and determine the cause of the problem.

6. A foggy or indistinct picture, after getting a sharp picture in a pipe, indicates that the viewport and possibly the optical lens of the camera have become fogged. This can take place shortly after a camera has started down the pipe, or it can occur after a camera has pulled past a service with hot or very warm water dumping out of it.

   a. A cold piece of glass placed in a warm and humid atmosphere will fog up. Use of some types of anti-fog compounds may be effective, but the best solution is to warm the camera before placing it in the pipe. A glass surface that is warmer than the atmosphere it is placed in will not become foggy.

b. When fogging occurs shortly after the camera enters the pipe, it is best to take the camera back out and put it where it can be warmed up to as much as 100°F (38°C). Avoid placing the camera in front of a heater where one side can be warmed more rapidly than the other. Possible ways of warming a camera are to put it in a warm room, or behind or under a cardboard cover in the sunlight, or in a vehicle parked in the sun with the windows closed.

c. When fogging takes place in a pipe after passing a service with hot water flowing out, simply stop the camera and wait for a few minutes. The warmth will be picked up by the glass parts and de-fogging will take place. Also the hot water may be cooled by the discharge of water from a fire hydrant.

d. Steam resulting from water striking the hot light assembly can be ignored. It will not last long and provides no serious problem to the picture.

7. Do not allow grease to accumulate on the light head. If the heat from the light ignites the grease, the light head could be damaged beyond repair. Also the fumes and stench from the burning grease that comes out the manhole has a horrible odor.

8. Be aware of the possibility that the TV camera could encounter explosive gas mixtures in a sewer. The heat from the light head may be sufficient to ignite certain explosive gas mixtures. Therefore, it is very important that a municipality or contractor use gas detection equipment prior to allowing manhole access to employees or equipment (see Section 5.33). *DO NOT OPERATE A TV CAMERA IN ANY LINE THAT TESTS POSITIVE FOR EXPLOSIVE GASES.*

9. If a sewer is flowing so full that the TV camera will be submerged, plug the sewer at the entrance to the upper manhole and televise the line as soon as the water drops. *BE CAREFUL THAT THE WASTEWATER HELD BEHIND THE PLUG DOES NOT BACK UP INTO SOMEONE'S HOME OR FLOW OUT THE TOP OF A MANHOLE.*

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 237.

5.43L List the types of conditions that the TV camera may encounter which require special precautions.

5.43M Why should you *NEVER* attempt to force a TV camera past an obstruction?

5.43N If a TV camera encounters a bad joint that it cannot pass, how can the remainder of the line be televised?

5.43O When coming out of a situation where the camera has been under water and the viewport is fouled with grease or other surface debris, what would you do?

5.43P What would you do if you were operating the TV monitor and observed a foggy or indistinct picture shortly after the TV camera entered the pipe?.

5.435 Shutting Down After Completion of the Pipe Run

When the TV operator is able to see the end of the pipe or the hardware in the downstream manhole, the operator immediately advises the pull winch operator of the situation. The pull winch operator continues with caution. When the swivel connection of the front tow cable touches the "downhole hardware," the TV operator gives the command to "STOP!" At this point, the inspection is completed and two (2) feet is added to the footage reading which is the remaining distance to the center of the downstream manhole. This information is added to the TV log as the total distance of the run. Shut-down procedures can now start.

The first act of the shut-down procedure is to turn off all power to the camera and light. *POWER MUST BE OFF BEFORE ANYONE ATTEMPTS TO HANDLE THE CAMERA OR PULL IT OUT OF THE PIPE.*

The standard light used on a sewer inspection television camera is a quartz-iodine type. These lamps, similar to a projection lamp, achieve extremely high temperatures (in some cases as high as 1,600°F or 870°C). The lamp and its reflector must be permitted to cool to a safe level before anyone handles the camera.

CAUTION: MOST CAMERAS AND MONITORS CONTAIN COMPONENTS THAT CAN BE DAMAGED BY FREQUENT OR SUSTAINED LOW POWER CONDITIONS. AVOID SIMPLY SHUTTING DOWN THE POWER GENERATOR AND ALLOWING THE ENGINE TO COAST TO A STOP WHILE POWER SWITCHES TO THE EQUIPMENT ARE STILL IN THE "ON" POSITION. SHUT OFF, LOCK OUT, AND TAG SWITCHES BEFORE SHUTTING DOWN THE GENERATOR.

5.436 Final Check of Television Survey and Footage Test

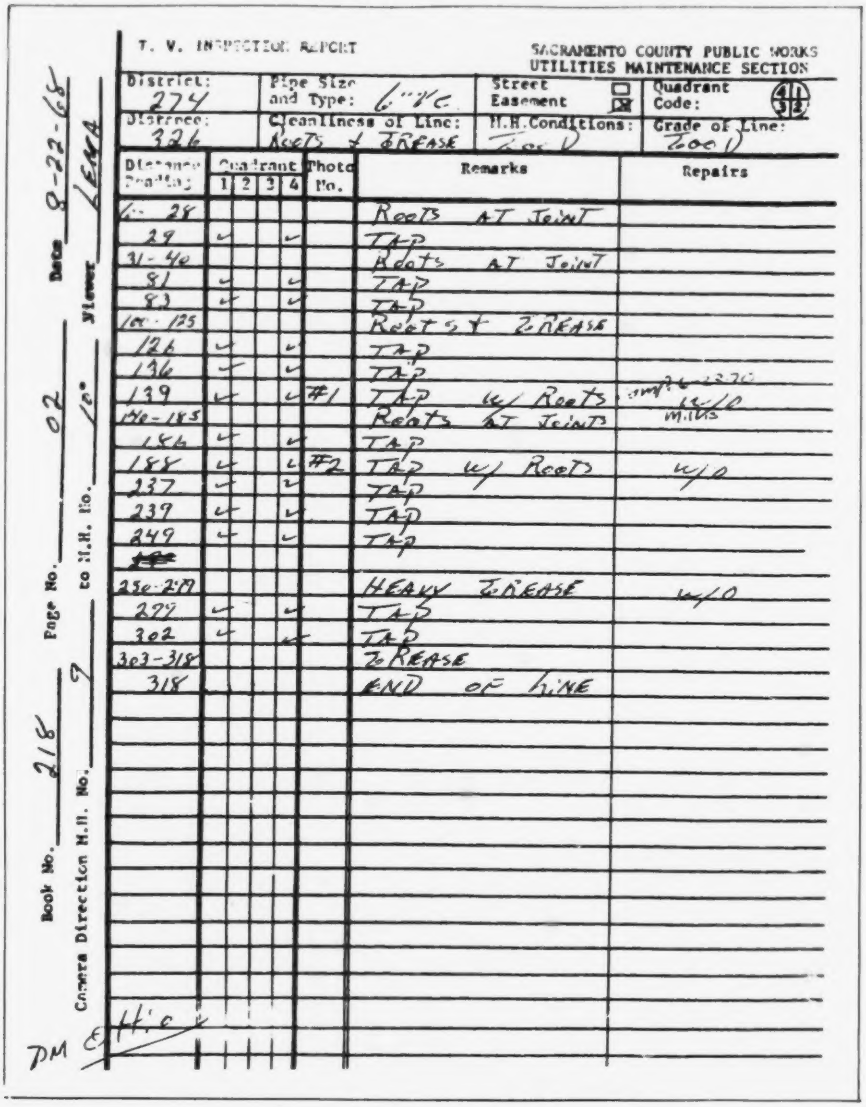
Before removing TV equipment from the manhole and turning in the television log sheet (Figure 5.14), every entry should be checked for readability, accuracy, and cleanliness. Poorly written entries or errors in the coded entries can cause costly losses. Dirty logs can make some of the notes and numbers unreadable.

1. Some types of footage meters can develop large errors during a television operation. In most instances this is due to slippage in the measuring device, or frequent backing and forwarding of the camera. To determine if such an error has taken place, compare footage meter distance with distance between manholes shown on wastewater collection system map. If a difference of more than one percent exists,[6] use a tape and measure the distance between the manholes. Also be aware of the fact that maps may contain distance errors. When repairs are necessary, distance errors can be very critical. If the TV operator determines that the errors are too erratic, the operator should see that repairs are made to the footage meter and the line be retelevised. Corrections on line distances, tap locations and other items should be routed to the mapping section so maps can be corrected.

   a. If a difference of more than one percent in the total distance measured and the footage recorded on the log is evident, add an error factor to the log. This error factor will be the amount of the difference. Give

---

[6] *See Appendix. Applications of Arithmetic to Collection Systems, Section M.9, Solutions to Problems, D. Slope and Grade, for an example of how to calculate the percent error in the footage meter.*



T. V. INSPECTION REPORT

SACRAMENTO COUNTY PUBLIC WORKS
UTILITIES MAINTENANCE SECTION

Book No. 218 Page No. 02 Date 8-22-68

Camera Direction M.H. No. 9 to M.H. No. 10° Viewer LEMA

District: 274	Pipe Size and Type: 6" VC	Street ☐ Easement ☒	Quadrant Code: 4 1 / 3 2
Distance: 326	Cleanliness of Line: Roots & Grease	M.H. Conditions: Good	Grade of Line: Good

Distance Reading	Quadrant 1	2	3	4	Photo No.	Remarks	Repairs
0-28						Roots at Joint	
29	✓			✓		TAP	
31-40						Roots at Joint	
81	✓			✓		TAP	
83	✓			✓		TAP	
100-125						Roots & Grease	
126	✓			✓		TAP	
136	✓			✓		TAP	
139	✓			✓	#1	TAP w/ Roots	w/o
140-185						Roots at Joints	Mills
186	✓			✓		TAP	
188	✓			✓	#2	TAP w/ Roots	w/o
237	✓			✓		TAP	
239	✓			✓		TAP	
249	✓			✓		TAP	
~~[illegible]~~							
250-279						HEAVY GREASE	w/o
279	✓			✓		TAP	
302	✓			✓		TAP	
303-318						GREASE	
318						END OF LINE	

Fig. 5.14 Completed CCTV inspection report

(Note 318 as end of line for last entry and line distance as 326)

Some operators prefer to use clock readings instead of the quadrant code (tap at 2 o'clock for example).

the error factor a sign which shows how the television log should be corrected.

b. Establishment of the error factor is important when it becomes necessary to excavate some point for repairs to the sewer. The correct distance permits a person to determine that some defect observed by the camera has to be a certain distance from the upstream manhole. If the error factor were not available, a person might dig at the logged footage, find that there was an error and then not know which direction and how far exploratory excavation should be made.

5.437 Removal of TV Equipment from Manholes and Preparation for Next TV Run

After the inspection report (Fig. 5.14) has been checked and found satisfactory, the TV equipment is removed from the manholes and made ready to be moved to the next section to be televised.

1. The pull winch operator winches the camera forward until the tow bridle is observed coming into the manhole. The tasks listed below are performed in sequence.

   a. Remove the fair lead hardware from the manhole.

   b. Move the pull winch stand from over the manhole to permit access into the manhole.

   NOTE: If possible, remove the camera without entering the manhole by using the pull cable.

   c. Observed manhole safety precautions (see Sections 4.3, *TRAFFIC ROUTING,* and 4.4, *MANHOLE HAZARDS*).

   d. Enter the manhole and first pull the camera forward by grasping the tow bridle.

   e. When the front of the camera has been pulled part way into the manhole, finger-tip check the temperature of the light assembly, NEVER TOUCHING THE LAMP ITSELF. If it is still quite hot, wait for it to cool to a point that it can be safely handled.

   f. As soon as the lamp assembly is cool, the viewport cover is installed on the camera. This cover protects the camera vidicon tube from the possibility of being pointed towards the sun while being removed from the manhole.

   g. After the cover is installed, the front tow cable is unhooked from the bridle and the camera pulled the rest of the way into the manhole.

   h. The tag line winch cable is next disconnected from the tag line bridle on some types of equipment. The pull winch operator tosses the hardware from this winch cable back into the pipe where it will not have a chance to tangle with the power cable strain relief and hook-up hardware. When this task is complete, the order is given "RETRIEVE THE TAG LINE." The tag line winch is then used to rewind the winch cable.

   i. The next step is to disconnect the power cables. Install the special plug or cap to prevent debris and moisture from getting to the electrical contacts at the end of the power cables. These plugs or caps are installed by the pull winch operators before the next step is taken.

   j. When the tag line winch cable has been pulled in adequately to prevent the ends of it and the power cable from getting tangled, the cable strain relief of the power cable is unhooked from the tag line bridle. The order can then be given to "RETRIEVE THE POWER CABLE."

   k. The camera assembly then may be removed from the downstream manhole and the manhole cover replaced carefully.

2. While rewinding the tag line and the power cable, the equipment is cleaned. This consists of wiping the cables free of any bits of paper or other debris as they are returned to the winch drum or cable reel (if used).

   a. Wiping is best done with a piece of foam rubber or a felt pad. Use of a cloth with threads can cause pieces of the cloth to be torn free and to wind around the cables.

WARNING

NEVER ALLOW A WINCH CABLE TO BE PULLED RAPIDLY BETWEEN THE BARE FINGERS OR BARE HAND. EVEN A LEATHER GLOVE IS NOT SAFE FOR THIS ACTIVITY. SMALL SINGLE STRANDS OF THE CABLE CAN BREAK AND STICK OUT WITH THE ABILITY TO RIP BARE SKIN. A SCRATCH FROM A CABLE THAT HAS BEEN IN A SEWER ALMOST PROMISES SERIOUS INFECTION.

   b. While wiping the returning cables, they are fed onto the drum or reel to effect level winding and avoidance of balling up at one point. A winch or cable reel permitted to ball up is able to become tangled and present problems when used on the next job.

3. If the camera and skid assembly are fouled with debris, they should be cleaned before storing or starting another run. Large clumps of debris are usually removed with a stick used as a scraper. A water jet from a garden hose is used to finish the job. Wipe the viewport dry as a final job.

   a. Where petroleum base residues are encountered and cause a camera and skid assembly to become coated, paint thinner or an approved solvent may be used to clean a camera. Do not use gasoline. Extreme fire hazard can result with the use of gasoline and gasoline can be harmful to seals on the camera. The camera should be thoroughly rinsed with water after cleaning. Keep cleaning chemicals away from the seals. Apply cleaning chemicals with a cloth and wipe away the chemicals immediately after cleaning.

   Whenever petroleum base residues are observed in a sewer, their location should be recorded and forwarded to your supervisor. The supervisor can determine the source of the discharge and decide if it is illegal. Also be aware that certain petroleum products can be ignited by the heat from the head lamp.

   b. Use of carbon tetrachloride or chlorthane chemicals for cleaning a camera or other parts should be avoided. Many of the polyesters used in seals and coatings of a camera and a cable are destroyed by these chemicals. Carbon tetrachloride also is hazardous to your health.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 237.

5.43Q What must be done before turning in the television log sheet?

5.43R Why should the distance measured by the footage meter be verified?

5.43S What is the first step of the shut-down procedure when the TV run has been completed?

5.43T What check should be performed on the light assembly before the viewport cover is installed on the camera and the camera removed from the manhole?

5.43U When the power cables are retrieved back up the sewer line, how are the electrical contacts at the end of the power cables protected from debris and moisture?

5.43V How would you clean the tag line and power cable while they are being removed?

5.44 Purchase of Closed Circuit TV Equipment

When your agency decides to purchase closed circuit TV equipment, the selection of a vendor, the type of equipment, accessories needed, and total overall operational cost are serious considerations. Perhaps the best place to start is to talk to other collection system operators and consider their experiences and recommendations to help make your decisions. Keep in mind that your particular needs are of primary importance. A piece of equipment must meet your needs and not someone else's needs. Equipment manufacturers' shows at national meetings such as the annual Water Pollution Control Federation Conferences provide an excellent opportunity to inspect the equipment of many manufacturers and also to discuss your needs with the manufacturers' representatives. If possible, arrange for a demonstration of the equipment you are considering purchasing so you and your crews can become familiar with the actual operation and performance of the equipment. See appendix at end of this chapter (Section 5.9) for details on desirable features of equipment.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 237.

5.44A How would you select the best closed circuit TV equipment for your agency?

5.45 Photographing the Television Monitor Picture

Permanent still photographic records of conditions in a wastewater collection system are frequently made by photographing the video picture in the television monitor. Any of several types of cameras may be used to take photographs; however, it is important to understand some details of photographic work in order to consistently get good results.

1. Only high-speed film should be used. While slower film can take photographs, the capacity to stop the action of water motion in a pipeline is lost and can result in blurred parts of the photo.
2. The television monitor is a weak source of light, especially where large parts of the video picture are dark. Because of lighting problems the camera must be held as close to the monitor as possible. This will require the use of a close-up lens on most cameras and the use of the smallest f-stop possible (resulting in the largest possible iris opening with the fastest possible shutter speed).
3. Time exposures of a television monitor are not recommended because the results are difficult to understand.
4. The most popular camera used for taking still photographs of the inside of a pipe shown on a television monitor is the polaroid. In addition to having a convenient and uncomplicated close-up kit available, it utilizes the fastest film available on the market in black and white (3,000 ASA).

Polaroid also is able to provide the resulting photograph in a matter of 15 seconds and assures that the scene desired is acceptable.

a. Because polaroid cameras have an automatic control for shutter speed and iris opening that is sensitive to the light entering the window of an electric eye on the camera front, only the light from the TV monitor should be permitted to fall on the camera front. This often requires the use of a hood to eliminate all other light between the camera and the monitor.

b. Where a hood is not used, all background light in the monitor viewing room should be eliminated when using a polaroid. The glass front of the monitor tube is highly reflective and any background light will be reflected back into the photographic camera, resulting in both faulty camera shutter adjustment and poor picture quality.

c. Black and white polaroid film is so fast that it is possible for the camera to stop the sequencing action of the television system. The average sewer inspection television system erases and builds a new picture 60 times per second. Between each picture the monitor may be dark or practically dark when the exceptionally high speed shutter of the polaroid camera records a picture. When this happens, the operator can only try again with the camera. A dark or blurred picture does not necessarily indicate any defect of the equipment or procedure.

d. Where video tape readout is not provided, all still photographs should be marked with the date and information regarding the line and footage location of the scene in the picture. In cases where a written television log is being kept, the photograph should be logged and the log entry number marked on the photograph. Most of these entries are made on the backs of the photographs after they are fully dry and can be handled without damage. Photographs can be inserted into individual clear plastic protectors and clipped or stapled to the written log sheet after each television run.

5.46 Use of Newer TV Equipment (Also see Appendix, Section 5.11, "Additional TV Inspection Equipment Information.")

In Sections 5.42, 5.43, 5.44 and 5.45 we discussed equipment, manpower, procedures, purchase and photographing with closed circuit TV equipment. The industry is continually striving to produce better and more cost effective equipment. Another consideration is to make the jobs of collection system operators easier and safer.

The previous sections emphasized one type of TV equipment to indicate to you the knowledge and skills necessary to televise a sewer. This section will inform you of some of the newer equipment available to televise sewers. Your equipment manufacturer will provide you with instructions on how to operate and maintain your TV equipment.

Some TV cameras can be inserted into and retrieved from sewers without an operator ever having to enter a manhole. Once the TV camera is properly positioned in the sewer to be televised, the TV operator focuses the camera from the station in front of the picture monitor (TV screen). The iris is automatically focused.

Modern closed circuit TV systems produce a TV picture in color instead of black and white. Color reduces eye strain on persons that must observe the TV picture or review video tapes all day. Infiltration problems are easier to evaluate in color due to a better perception of the rate of infiltration.

After a TV camera is properly positioned in the sewer to be televised, the TV operator is the only person needed to televise a sewer. The TV operator regulates both the power winch (pull winch) and power reel (tag line or return winch) while viewing the TV picture monitor. If the camera approaches a tight spot or starts to get stuck, the power winch in front of the TV operator will start to slow down. An alert operator can stop the camera before it gets stuck. If the camera does get stuck or if the power winch cable breaks, the camera can be pulled back by the power reel. A much stronger cable is used on the power reel in order to retrieve the camera if the camera gets stuck.

5.47 Use of 3D Photography

Another method of inspecting sewers is by the use of 3D photography. To use this technique, a camera is placed on skids and pulled through the sewer. As the camera travels through the sewer, a photograph is taken every three or four feet. A special viewer is used to produce a three-dimensional photo of the sewer. This procedure is much cheaper than using closed circuit television. A disadvantage is that if you need more photos or details, you don't find out until a couple of days later after the film has been developed and studied.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 237.

5.45A How can photographs be made of a problem inside a pipe?

5.45B What kind of film should be used to take photos of the video picture in the TV monitor?

5.45C What kind of camera is most commonly used to take photos of the video picture in the TV monitor?

5.45D What information should be attached to a photograph taken of the inside of a pipe?

END OF LESSON 3 OF 5 LESSONS
ON
INSPECTING AND TESTING COLLECTION SYSTEMS

DISCUSSION AND REVIEW QUESTIONS

Chapter 5 INSPECTING AND TESTING COLLECTION SYSTEMS

(Lesson 3 of 5 Lessons)

Write the answers to these questions in your notebook before continuing. The problem numbering continues from Lesson 2.

12. What information can be obtained from a closed circuit television inspection of a sewer?
13. What must a collection system crew do *BEFORE* starting to set up the TV inspection equipment?
14. How is the TV inspection camera moved through a sewer?
15. How does a TV inspection crew communicate with each other?
16. What conditions require that special precautions must be taken when inspecting sewers with a TV camera?
17. How is a TV camera removed from the sewer after an inspection run is completed?
18. Why must the distance recorded by a footage meter be compared with the actual measured distance?

Chapter 5. INSPECTING AND TESTING COLLECTION SYSTEMS

(Lesson 4 of 5 Lessons)

5.5 SMOKE TESTING

5.51 Purpose

Use of smoke for testing sewers is best done when the groundwater is low so any cracks will leak smoke. Realize that the location of smoke on the ground surface does not necessarily reveal where the smoke is escaping underground, but only the path of travel to the ground surface. Smoke testing of wastewater collection systems (Fig. 5.15) is used to determine:

1. The sources of entry to the collection system of surface waters, also called surface inflow. This includes rain or storm waters, street or surface wash waters, and in some cases, irrigation waters.
2. Positive proof that buildings or residences are connected to a wastewater collection system.
3. Location of certain types of illegal connections to a wastewater collection system. Included with these connections are such things as roof leaders or downspouts, yard drains, industrial drains, and some types of cooling tower water drains.
4. Location of broken sewers due to settling of foundations, manholes and other structures.
5. Location of "lost" manholes and diversion points.

5.52 Equipment

All of the following equipment are used or are applicable to a smoke testing operation:

1. Smoke blower unit (Figure 5.16). This is usually a squirrel cage blower with a gasoline engine and belt drive. The average blower capacity will be over 1,700 CFM and under 3,000 CFM. The blower will have a base with a rubber gasket underneath the base that permits it to set over and force a blast of air into an open manhole.
2. Pipe plugs (Figure 5.17) to isolate two sections of pipe between three adjacent manholes. These may be mechanical or inflatable.

   Where there are high wastewater flows that prevent safe plugging of a line to be smoke tested, heavy canvas or curtains with weights or sand-bags on the bottom may be used to confine the smoke to the section being tested (Section 5.54).
3. Smoke bombs (Figure 5.18) of the three minute or five-minute duration type.

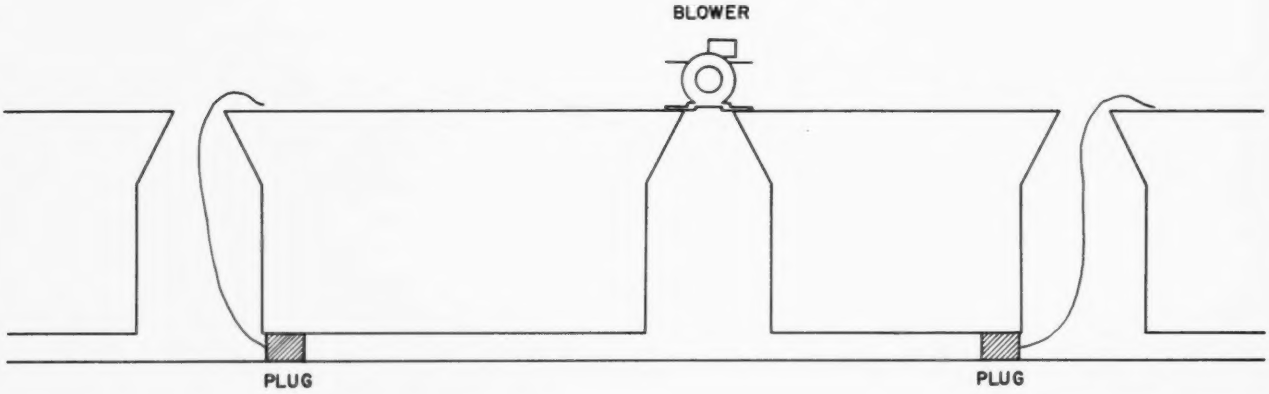


Fig. 5.15 Smoke testing

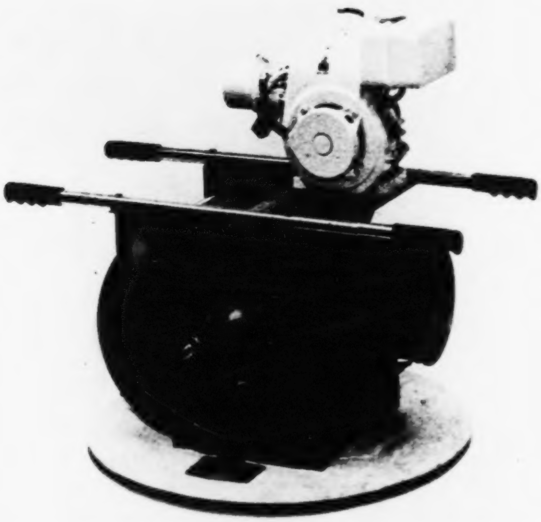


Fig. 5.16 *Manhole smoke blower. Fiberglass base fits over opening of manhole and small port for suspending smoke bomb on wire or chain.*

(Courtesy of Superior Signal Company, Inc.)

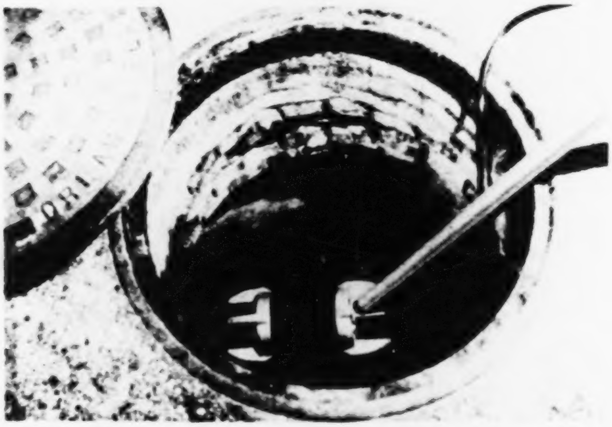


Fig. 5.17 *Pipe plug. An inflatable pipe plug that can be installed and removed without having to enter a manhole. This provides maximum safety and speed for smoke testing work by eliminating the need to enter the manhole.*

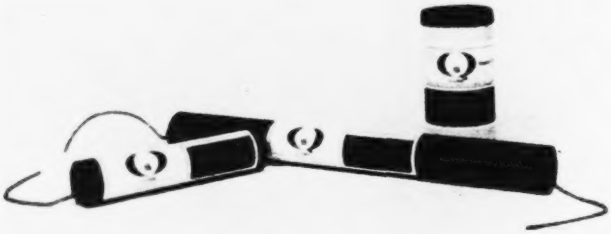


Fig. 5.18 *Smoke bombs*

WARNING: USE ONLY MAILABLE SMOKE BOMBS SPECIFIED TO BE SAFE AND TO HAVE NO TOXIC OR RESIDUAL EFFECTS. NEVER USE MILITARY TYPES OF COLORED OR SIGNAL SMOKE BOMBS FOR THIS APPLICATION DUE TO EXPLOSIVE DANGER AS WELL AS DANGER FROM CONTACT TO OPERATORS AND PROPERTY.

5.53 Preparations

Smoke testing of wastewater collection systems has a chance to affect the occupants of buildings connected to the line being tested. Such factors as defects in the sewer system of the buildings, dry traps, defective wax ring under commodes, vents terminated in an attic, or clean out plugs missing from sewers can cause smoke to enter the building. Adequate preparation plus good advance public relations is a necessity in order to avoid panic or severe alarm among persons having the smoke enter a building or a home.

1. Warn the public in advance when and where smoke testing is planned. A typical public announcement is shown in Figure 5.19. This type of announcement should be published in a local paper and be prominently displayed and distributed in the area to be smoke tested. Occupants should be requested to run some water into sewers that are not used regularly before the test starts to fill traps that may have dried out.
2. *THE LOCAL FIRE AND POLICE DEPARTMENTS MUST BE THOROUGHLY BRIEFED ON THE SMOKE TESTING OPERATION AND ITS SAFETY.* In addition, the fire department should be advised of the area to be smoke tested at the start of each day of testing. If possible, it is a good idea to have a vehicle from the fire department with one or two members of that department accompanying the smoke testing operation.

PUBLIC NOTICE

TO ALL OCCUPANTS AND RESIDENTS:

THE CITY WILL BE CONDUCTING LEAK TESTS IN THE SANITARY SEWER SYSTEM BY BLOWING SMOKE INTO THESE PIPES. THIS SMOKE WILL REVEAL SOURCES OF SEWER ODORS IN YOUR NEIGHBORHOOD AS WELL AS PLACES WHERE STORM AND OTHER SURFACE WATERS ARE ENTERING THE SANITARY SYSTEM.

A SPECIAL, NON-TOXIC SMOKE WILL BE USED IN THESE TESTS. THIS SMOKE IS MANUFACTURED FOR THIS PURPOSE, LEAVES NO RESIDUALS OR STAINS AND HAS NO EFFECTS ON PLANT AND ANIMAL LIFE. THE SMOKE HAS A DISTINCTIVE, BUT NOT UNPLEASANT, ODOR. VISIBILITY AND ODOR LAST ONLY A FEW MINUTES, WHERE THERE IS ADEQUATE VENTILATION.

BECAUSE THE PLUMBING APPLIANCES IN YOUR HOUSE OR BUILDING ARE CONNECTED TO THE SANITARY SEWER SYSTEM, SOME OF THIS SMOKE MAY ENTER YOUR HOUSE IF THE:

- VENTS CONNECTED TO YOUR BUILDING'S SEWER PIPES ARE INADEQUATE, DEFECTIVE OR IMPROPERLY INSTALLED.
- TRAPS UNDER SINKS, TUBS, BASINS, SHOWERS AND OTHER DRAINS ARE DRY, DEFECTIVE, IMPROPERLY INSTALLED OR MISSING.
- PIPES, CONNECTIONS AND SEALS OF THE WASTEWATER DRAIN SYSTEM IN AND UNDER YOUR BUILDING ARE DAMAGED, DEFECTIVE, HAVE PLUGS MISSING OR ARE IMPROPERLY INSTALLED.

ALL RESIDENTS ARE ADVISED THAT IF TRACES OF THIS SMOKE OR ITS ODOR ENTERS YOUR HOUSE OR BUILDING, IT IS AN INDICATION THAT GASES AND ODORS FROM THE SEWER ALSO MAY ENTER. THESE CAN BE BOTH UNPLEASANT AND DANGEROUS AS WELL AS A HEALTH HAZARD TO THE OCCUPANTS. LOCATION, IDENTIFICATION AND CORRECTION OF THE SOURCE OF SMOKE THAT ENTERS YOUR HOUSE IS URGENTLY ADVISED.

WHILE THE CITY WILL RENDER ALL POSSIBLE COOPERATION, THE CORRECTION OF ANY DEFECTS IN THE PIPES AND SEWER ON PRIVATE PROPERTY IS THE RESPONSIBILITY OF THE OWNER. THE SERVICES OF A PROFESSIONAL PLUMBER ARE ADVISED.

IF YOU HAVE ANY QUESTIONS OR DESIRE MORE INFORMATION, PLEASE TELEPHONE THE CITY OFFICES DURING REGULAR OFFICE HOURS.

CITY MANAGER

Fig. 5.19 Typical public announcement

3. All operators who will participate in the smoke testing should be fully trained and daily briefed in the proper method of handling persons who discover smoke in their homes or smoke coming up all over their yard and around their house. Anticipate that such a circumstance will occur and that it can have a potential for generating considerable concern among certain types of individuals.

   a. Operators on the team should be drilled in the concept that any smoke entering a building or residence reveals that gases from the sewer can and do enter the building. Prompt correction of the problems by the owner is necessary for the health and safety of the building's occupants.

   b. Where smoke is coming from a drain in a plumbing fixture, first inspect the trap water seal to determine if the trap is dried out or is defective. Where a trap is dried out and unlikely to be used, suggest that the traps be filled with mineral oil. Do not put mineral oil into a trap that will be used occasionally.

   c. A missing wax ring under a commode is easy to identify and to tell a householder how to solve. In any event, a plumber can replace a wax ring.

4. There are conditions where an observer and recorder may enter private property, therefore adequate consideration of, and good public relations with owners and occupants must be exercised.

   In a city that had a rash of Peeping Tom reports, women were employed as observers and reporters during smoke testing activities. While an irate and disturbed citizen might accuse a male city employee of compromising the privacy of her bedroom window, it is unlikely that she would throw the same charge at a female. Advance publicity, identifiable clothing for operators, signs on equipment, and good public relations all help to avoid upsetting the public.

5. A city or agency attorney should be advised of the smoke testing methods and some of the possible adverse results. Although there is no basis for damage or tort (civil) claims from a building owner for smoke disturbance or alleged damage to interiors, such claims may require defense by an attorney. Discuss with the attorney what kind of information and reports are needed if any incidents or difficulties arise during smoke testing.

6. Crew that does smoke testing should inspect the area to be tested in advance in order to become familiar with the area.

5.54 Manpower

The average smoke testing crew consists of five persons. One person in charge (Maintenance Man II) and four observers and recorders (Maintenance Man I).

When there is a high flow in the pipeline to be tested and a chance of surcharging and overflowing an upstream manhole above the plugged off test section, a sixth person is needed to keep watch on the manhole.

When a manhole that must be watched appears to be subject to surcharge and overflow, use of a sandbag on a rope is perhaps the best answer. The sandbag plug may be pulled up long enough to allow the manhole to drain, then replaced as required. For best results, sandbags are tied in the middle so the chance of loss is decreased as much as possible.

Another method of closing off a pipe run for smoke testing where high flows exist is the use of curtains. These are pieces of canvas with weights on the bottom or a similar material with a rigid frame member along the top edge. They are lowered on a rope until they touch the surface of the flow and then they are tied in place. These curtains must be tight around the edges to prevent smoke leaks.

5.55 Operation

At the start of the operation, the smoke blower is located over the manhole and the ends of the pipes plugged at the next adjacent manholes. Smoke testing should not be attempted on windy days. Even a very light breeze can disperse a wisp of smoke before it is visible at a vent or the source of a leak.

1. The blower is started and allowed to force air into the pipe system for five to ten minutes or longer (depending on volume of sewer being tested) before any smoke bomb is lit.

   The purpose of forcing air into the pipe system is to get an air flow established. Since air has weight and inertia, it sometimes takes even longer than five or ten minutes to achieve a flow of air through a pipe system. Once a flow of air is properly established, the air will carry the telltale smoke along with it rather than have the blower try to push a wad of smoke into a pipe system.

2. Once the air flow is established, one or more smoke bombs are lit and lowered into the manhole at the blower on metal chains, or short lengths of wire. Hooks made of coat hanger wire are often used for this purpose.

   Smoke bombs have a cardboard cylinder with the smoke making chemicals inside and a single paper cover on the outside. The cardboard cylinder has perforations where the smoke escapes at frequent locations and these can be located with fingertip pressure. The perforated holes provide suitable places for a wire hook to be inserted in the smoke bomb.

3. As soon as the bomb has been lit and put into the manhole, the observers and recorders move out according to prearranged plans. One observer takes one side of the street and moves away from the manhole being smoked, observing the buildings on that side of the street. Another observer moves in the same direction on the other side of the street. The other two observers move in the opposite direction after inspecting the immediate area outside of the manhole.
   a. Where proper building plumbing exists, smoke will come from the roof vents of the building drain system.
   b. The observers must look at all other parts of the building (inside and outside) and its grounds (front, back and side yards) for other indications of smoke from illegal connections.
   c. Before moving on to the next house or building, the observer takes a careful look at the foundation of the building, particularly where the house service pipe would usually pass under the foundation footing.
4. The observer will cover one side of the distance between the manhole smoked and the next adjacent manhole that has been plugged.
5. In the event the smoke supply of the first bomb runs out before the area is fully observed, a second or additional bombs may be needed. One five-minute bomb is usually all that is needed (100,000 cubic feet of smoke) for a two-city block run, or approximately six hundred feet of pipe run. Where there are time comsuming conditions in the inspection process, as many as five or six bombs may be necessary.

5.56 Recording

Observers should record every building and the observed results of the smoke test. House numbers are generally sufficient for the recording purpose. Typical entries might include:

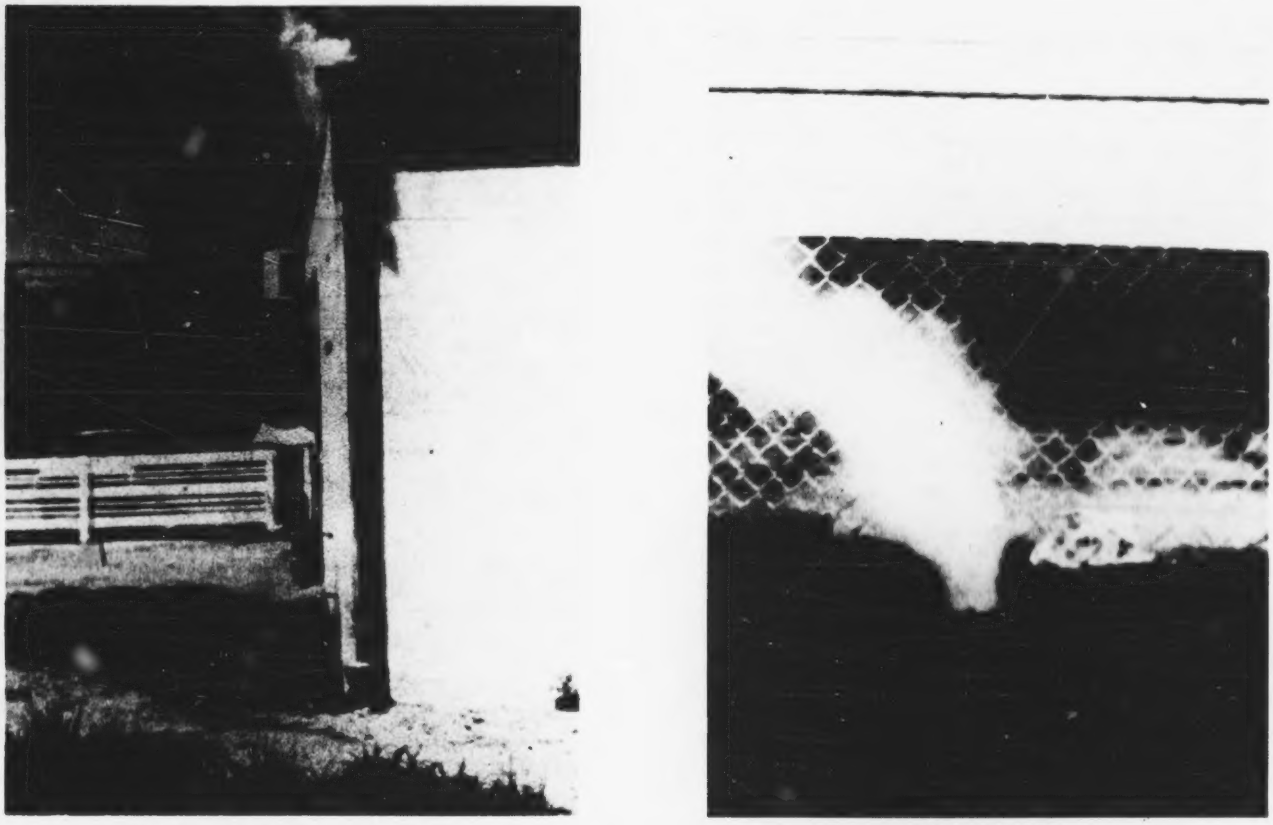
1. "265 Brown Street — smoke from vents only." This is a no-problem house as far as the smoke test was concerned.
2. "269 Brown Street — smoke from ground at building foundation, SE corner in front." This reveals what could be a source of inflow to the sewer as a result of the building sewer broken at the foundation. This is not uncommon when such pipes are laid shallow and often butted up under the house foundation. When the foundation settled, the pipe was crushed or disjointed.
3. "273 Brown Street — no smoke from vents." There may be a dip or a trap in the house sewer to the lateral. If none of the rest of the buildings beyond this house have smoke showing at vents, this is an indication that the lateral sewer has a dip in it that has created a trap. Another possibility would be a stoppage in the sewer that could result in wastewater backing up into the house.
4. "277 Brown Street — smoke from rain gutters." The roof leaders apparently are connected to the building drains. This is a source of inflow.
5. Any location where smoke is showing should be fully described and recorded. If smoke shows at the windows inside of an un-occupied building, it should be recorded with a note stating that the building appeared to be vacant or may have had occupants that were absent at the moment.

   When this occurs, the observer should place a copy of the public announcement (Figure 5.19) where someone entering the house will find it. Letting such a person know that any odd odor found in the building could come from the sewer is a point of safety as well as concern. Also notify the health department or police to be sure corrective action is started immediately and that people are not allowed to live in the house until the problem is corrected. Making people vacate and stay out of a building is the responsibility of the health department and police department, not the job of the collection system operator.

Typical results from smoke testing are shown in Figures 5.20 and 5.21. Whenever possible, photograph illegal situations. Photos are a valuable record.

5.57 Other Considerations When Smoke Testing

1. Smoke testing may be used to locate points of inflow or exfiltration, but does not measure the amount of inflow or exfiltration.
2. Basement sump pumps have little chance of detection by smoke even when they have discharge connections to the building sewer. This is due to the usually required use of check valves in any sump pump tie-in to a building sewer and also the fact that the intake is submerged in water which forms a trap.
3. Where smoke appears at the vent pipe of a house, it is positive evidence that the house is connected to a sewer that is being smoked. Service districts which have monthly billings to property owners connected to a wastewater collection system thus have definite proof of a connection.
4. Where no smoke appears at a house vent, it does not mean that such a house is not connected to the sewer. Tests have shown that there are many houses with drain grade defects in service connection pipes, or may even have a trap installed in such a pipe. Many buildings that are connected to combined sewers have traps in the service line. Some buildings that may have been on a septic tank in the past may still be on such a tank with a connection from the discharge of the tank to the sewer. Under these circumstances, a well designed tank with baffles as required or an old tank with collapsed pipes and baffles may not permit the smoke to pass through.
5. There are some cities and counties in the United States where modern enforcement of plumbing codes fails to adequately protect a service district. The admission of smoke into a building from sewer smoke testing usually indicates a health or plumbing code violation in the building's utilities. If smoke is found in a building, look for a dry trap from a basement shower, toilet or drain that has not been used recently *BEFORE* deciding there is a violation.

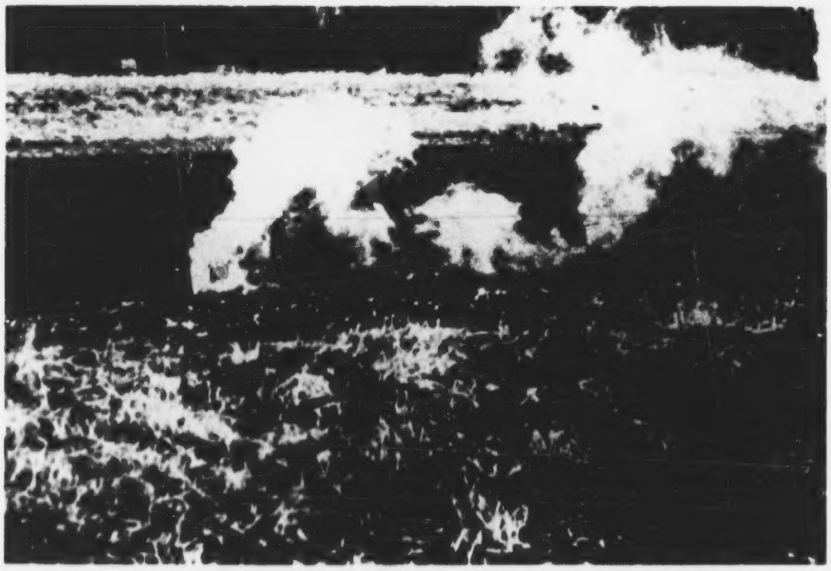


Building rain gutter connected to sewer system

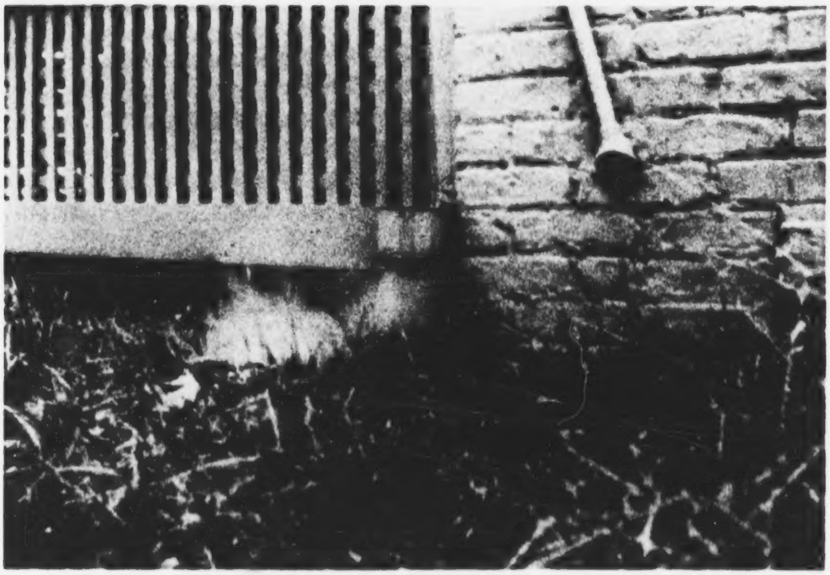
Cleanout for building sewer that is uncovered and unsealed

Smoke from building sewer vent indicates smoke test is effective

Fig. 5.20 Smoke test results



Smoke from yard drain illegally connected to wastewater collection system.



Smoke reveals the foundation settled and cracked or broke sewer pipe. Storm water from adjacent roof leader created open channel into the break in the sewer pipe.

Fig. 5.21 Smoke test results

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 238.

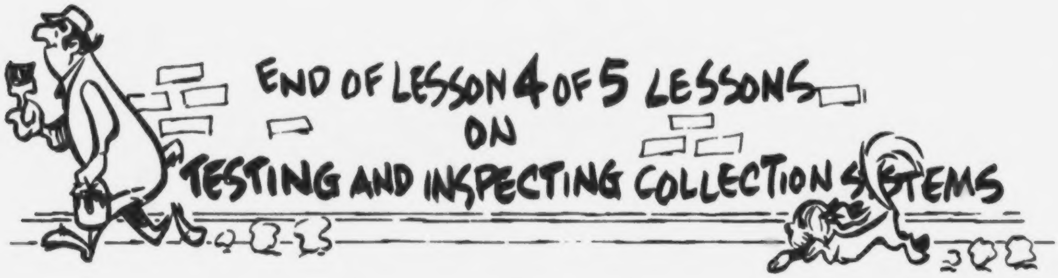
5.5A What is the purpose of smoke testing?

5.5B List the equipment needed for a smoke testing operation.

5.5C What preparations should be taken before starting a smoke testing program?

5.5D Why is the blower started and allowed to force air into the pipe system for five to ten minutes before a smoke bomb is lit?

5.5E Where should observers look for smoke?


END OF LESSON 4 OF 5 LESSONS
ON
TESTING AND INSPECTING COLLECTION SYSTEMS

DISCUSSION AND REVIEW QUESTIONS

Chapter 5. INSPECTING AND TESTING COLLECTION SYSTEMS

(Lesson 4 of 5 Lessons)

Write the answers to these questions in your notebook before continuing. The problem numbering continues from Lesson 3.

19. Why are sewers smoke tested?

20. How would you handle a scared and irate citizen whose home was filled with smoke from a smoke testing operation?

Chapter 5. INSPECTING AND TESTING COLLECTION SYSTEMS

(Lesson 5 of 5 Lessons)

5.6 DYE TESTING

5.61 Purpose

Dye testing is being used to establish positively if certain facilities or fixtures are connected to a wastewater collection system. Illegal connections can be identified using dye tests. If wastewater is overflowing or reaching a creek, river or estuary, dye testing can be used to identify the overflowing or leaking sewer. Also dyes are used to reveal interconnections between sanitary and storm sewers. Specially manufactured dyes are available for this type of testing. Examples of typical dye tests include:

1. Buildings that may not show smoke at vents during smoke tests due to dips or traps in the service connection pipes can be dye tested,
2. Where a yard drain or storm drain is suspected of being tied to the building sewer or a lateral sewer, a dye test is useful, and
3. Any suspected situation of inflow or surface drainage may be checked out by using a dye.

Other uses of dye testing include estimating the velocity of flow and testing for infiltration and exfiltration. By pulling a bag of dye up a sewer and stopping at short intervals, an area of exfiltration can be located that could not be seen on a TV inspection such as an open joint that is in line and on grade.

5.62 Equipment

Contact the water pollution control agency to determine if there are any regulations regarding the use of dyes.

Two types of safe and harmless but effective dyes are available for dye testing. Powder in cans or containers is measured by a spoon or small dipper. Tablets of the dye are slower to dissolve than the powder form, but are less messy and are sometimes more desirable than the powder for this reason. The dye is the only piece of equipment needed. Regardless of the type of dye, dissolve it in the flow. A tablet may sink into a sump or wet well and not circulate with the usual flow.

CAUTION: Some dyes may leave a stain if spilled. These stains can be very difficult to remove.

5.63 Operation

For the purpose of maintaining good public relations, the public should be notified of your plans for dye testing programs. This is especially so when it becomes necessary to perform work within private property.

While one operator applies the dye to the suspected location, another operator maintains a watch at the next downstream manhole from the location.

1. Where a plumbing fixture is used, such as a closet bowl or basin, the water is turned on and the dye powder or tablet is dropped directly into the drain.
2. Where there is no immediate supply of water, such as a roof gutter or storm drain in dry weather, pouring a bucket of water with dye powder is suggested. The amount of water and dye needed depends on the distance to the next manhole and the existing flow.

3. Based on an assumed velocity of flow, an estimate may be made of the expected flow time to the downstream manhole. Allow plenty of time because the dye often takes much longer than expected.
4. Use of powdered dye can be difficult and messy on a windy day. When the wind blows, either pre-mix the dye in water or enclose a quantity of the powder dye in either kleenex tissue or toilet paper. Once wind scatters a powdered dye, the dye is impossible to collect and nearby residents of homes and businesses can become very upset when the dye lands on their property, gets wet and causes stains on their buildings, autos, clothes and landscaping.
5. When a number of dye tests are to be conducted on the same line or section of a sewer system, the dye testing should start at the facility farthest downstream and progressively work upstream for the other dye tests. Otherwise, if you dye the facilities upstream first, the flow is then contaminated with dye, and you then must wait several hours or until the next day to conduct additional tests.
6. When the tests are completed, record whether or not the service is connected to the sewer.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 238.

5.6A What is the purpose of dye testing?

5.6B What equipment is needed for a dye test?

5.7 PIPELINE LAMPBING[7]

5.71 Purpose

Lamping sewers from manhole to manhole has been done for many years. The purpose of lamping is to establish that a section of pipe is straight and open or that it is not. Lamping also permits an inspector to visually examine conditions in a pipe within viewing distance of the manhole, usually a very few feet in this case. Larger sewers are easier to lamp than small sewers.

---

[7] *Lamping. Using reflected sunlight or a powerful light beam to inspect a sewer between two adjacent manholes. The light is directed down the pipe from one manhole. If it can be seen from the next manhole, it indicates that the line is open and straight.*

5.72 Equipment

A bright source of light and a mirror are all that are needed for simple lamping. In some cases, two or more mirrors are used to direct sunlight from the surface of the ground into the manhole to another mirror and then into the line.

5.73 Manpower

Four persons are usually needed for pipeline lamping, provided the two workers topside can easily contact the other if help is needed (1 foreman and 3 sewer service workers).

5.74 Operation

Be sure the manhole is safe to enter by following the instructions in Section 4.3, "Routing Traffic," and 4.4, "Manhole Hazards."

TRAFFIC ROUTING
HI! PLEASE TURN BACK AND REVIEW SECTION 4.3 ON PAGE 116

MANHOLE HAZARDS
HI! PLEASE TURN BACK AND REVIEW SECTION 4.4 ON PAGE 124

1. One operator enters a manhole and either looks up the pipeline directly or looks up the sewer using a mirror. For smaller sewer lines, a mirror may be required. The operator in the manhole can use the mirror both to reflect sunlight and at the same time to look into the sewer.
2. A second operator enters the next manhole up or down the line and shines a bright light directly down the pipe towards the first operator. The light or mirror is moved around to be sure the light is directed down the pipe. If the first operator can see the light, the line is deemed to be open and straight. If the light is not seen, the line is deemed to be either "off-line" or "obstructed."
3. When the first operator is able to see the light, an operator topside is notified who signals the crew directing the light. Signals or voice communications must be established between crews when the light is directed down the sewer and when it is seen at the other end of the sewer.
4. Best lamping results are obtained by rotating the light source around the inside of the pipe. This method will produce more information than a stationary light.
5. Another device used for lamping is an inverted (up-side-down) periscope with a changeable focal length from zero to 500 feet. A light source is introduced in the same manhole where the periscope is inserted. The results are quite graphic and the optical system can be calibrated to produce suitable readings within acceptable tolerances.

5.75 Comments

Lamping is an economical and fast method of determining if a sewer line is straight and clear of obstructions. However, in small diameter sewers it has limited use and alternative methods must be used to establish their condition. More popular methods include low pressure air testing and CCTV inspection. In large sewers where the flow can be diverted or held, the sewer can be walked and inspected using a good light or a hand held camera.

Lamping should never be used as the sole means of acceptance testing of new sewer lines. The existence of cracks, infiltration or other pipe problems which do not affect pipe alignment are difficult, if not impossible, to detect by this method.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 238.

5.7A What is the purpose of pipeline lamping?

5.7B Can lamping be used to locate sources of infiltration?

5.8 AIR AND WATER TESTING

If you have a need to test sewers for leaks using air or water testing methods, refer to the Supplement of Chapter 3, Section 3.85, "Air Testing," and Section 3.86, "Water Testing."

END OF LESSON 5 OF 5 LESSONS
ON
TESTING AND INSPECTING COLLECTION SYSTEM

DISCUSSION AND REVIEW QUESTIONS

Chapter 5. INSPECTING AND TESTING COLLECTION SYSTEMS

(Lesson 5 of 5 Lessons)

Write the answers to these questions in your notebook before continuing to the objective test on page 238. The problem numbering continues from Lesson 4.

21. What is the main reason for conducting a dye test instead of a smoke test?
22. Under what circumstances would you lamp a sewer?

SUGGESTED ANSWERS

Chapter 5. INSPECTING AND TESTING COLLECTION SYSTEMS

ANSWERS TO QUESTIONS IN LESSON 1

Answers to questions on page 181.

5.1A Wastewater collection systems should be inspected and tested to

1. Identify existing and potential problem areas,
2. Evaluate seriousness of detected problems,
3. Locate position of problems, and
4. Provide clear, concise, and meaningful reports to supervisors regarding problems.

5.1B Leaks are a problem because they allow

1. Infiltration that uses valuable pipe and plant capacity,
2. Exfiltration that could pollute groundwater and surface water, and
3. Root intrusion into sewers.

Answers to questions on page 182.

5.2A The purpose of inspecting wastewater collection systems is to look for the causes of problems or the start of potential problems. Once a problem has been identified, its exact location must be determined. The size and kind of problem must be identified so the problem can be solved.

5.2B Major sources of wastewater collection system problems include

1. Design related deficiencies,
2. Improper installation,
3. Inadequate sewer-use ordinances,
4. Improper inspection and enforcement,
5. Changing patterns of population shifts and activities,
6. Disaster or contingency situations,
7. Problems of recurrent nature,
8. Problems characteristic of region,
9. Poor coordination between local agencies, and
10. Problems related to a tired and frequently forgotten wastewater collection system.

Answers to questions on page 184.

5.2C Inflow and infiltration must be controlled to prevent hydraulic overloads of the collection system or the wastewater treatment plant.

5.2D The sources of inflow include (1) deliberate connections, and (2) surface drainings.

5.2E Sources of infiltration can be identified by the use of closed circuit television, flow metering devices, smoke testing, dye testing and visual inspection.

5.2F Infiltration problems can be corrected or eliminated by (1) sealing using pressure grouting, (2) digging up and replacing pipe, and (3) inserting a plastic liner.

5.2G Exfiltration must be controlled because it can cause pollution of groundwaters.

ANSWERS TO QUESTIONS IN LESSON 2

Answers to questions on page 186.

5.3A Manholes should be inspected to be sure the lid is at the proper elevation, the manhole is structurally sound and is performing its intended job.

5.3B One person can inspect a manhole, but assistance may be needed to route traffic or to enter the manhole.

5.3C When inspecting a manhole, examine the following items:

1. Elevation of lid,
2. Insects under lid or in manhole,
3. Surfaces and joints inside manhole
    a. Cracks or breaks
    b. Infiltration
    c. Joints
    d. Offsets
    e. Roots
    f. Grease
    g. Gravel or debris
    h. Turbulence
    i. Grout bed of frame
    j. Steps
    k. Shelf
    l. Flow
    m. Corrosion
4. Noises that indicate infiltration or turbulence from cracked or broken pipes,
5. Manhole ring, and
6. Fit of lid.

5.3D Manholes should be inspected once every one to five years with those in areas of heavy traffic being inspected more often.

ANSWERS TO QUESTIONS IN LESSON 3

Answers to questions on page 199.

5.40A Testing and inspecting collection systems must be done thoroughly and on a regular basis to reduce the number of stoppages and failures.

5.41A Closed-circuit television inspection provides the opportunity to actually see the problems in a sewer, locate the problems, and evaluate the effectiveness of corrective action.

5.41B The following kinds of information can be obtained from a television inspection of a collection system.

1. Inspect conditions and determine location of problem areas,
2. Look for damage to sewers,
3. Search for unrecorded connections,
4. Locate inflow and infiltration,
5. Inspect installed and/or repaired taps or pipes, and
6. Evaluate effectiveness of solutions and equipment.
7. Locate buried or lost manholes.

5.42A A collection system television crew usually consists of three people, plus additional help when working in heavy traffic and congested areas.

Answers to questions on page 205.

5.43A The TV camera should *ALWAYS* be pulled from the upstream manhole to the downstream manhole for the sake of consistency. Also there is a lesser chance of the camera becoming stuck in older lines. Pulling the camera towards the downstream manhole also helps to prevent a buildup of rags and debris in front of the lens.

5.43B When a TV camera crew arrives at a sewer to be inspected with a TV camera, *SAFETY SHOULD BE THEIR FIRST CONSIDERATION*. Safety cones and flags should be properly placed to protect the crew and the equipment. The crew should wear hard hats and *REFLECTIVE SAFETY VESTS*, the manholes should be inspected for hazardous atmosphere and conditions, and the manholes should be ventilated.

5.43C The TV pull winch is located at the downstream manhole so the winch cable can pull the TV camera from the upstream to the downstream manhole.

5.43D The proper skids are important because the camera lens must be as close as possible to the center of the pipe when the camera moves down the pipe.

5.43E The pull winch cable is kept from rubbing on the pipe at the downstream manhole by the fair lead equipment. This equipment consists of a set of pulleys or jacks with pulleys placed in the manhole. A "shoe" is also used which allows the cable to slide around a bend on a smooth surface.

5.43F The footage meter should be set to read zero at the center of the manhole.

5.43G Two essential rules that must never be violated while the TV camera is moving down the line are:

1. The operator must *NEVER* stop looking at the monitor picture. Any obstruction that could wedge or damage the camera or the light must be seen in time to stop the camera's progress, and
2. If communications with the operator at the pull winch are lost, progress must be stopped immediately.

5.43H If a camera and skid assembly become wedged or locked in a pipe and the pull cables break, the pipeline must be dug up to recover the camera.

Answers to questions on page 208.

5.43I The TV camera must be stopped while the operator records data because the operator must stop looking at the TV monitor (screen) while writing the information.

5.43J A polaroid camera is used to photograph infiltration points, bad offsets, damaged laterals, root growths, and broken pipes. The photo provides an excellent record for supervisors to schedule repair work and for repair crews to visualize the problem to be corrected.

5.43K Some of the advantages of using a video tape over a polaroid camera include

1. The operator's voice can describe the problem while people watch the picture,
2. The video tape records motion, such as infiltration flows, and
3. If a pipe is off grade, the video tape can show the extent and magnitude of the defective area.

Answers to questions on page 220.

5.43L Conditions the TV camera may encounter which require special precautions include:

1. Offset joints that restrict the pipe diameter can cause a camera to wedge tightly in place,
2. When the TV camera goes under water it becomes impossible to see obstructions,
3. When the TV camera emerges from being under water, the picture can be foggy or indistinct which can reduce the effectiveness of the visual inspection,
4. Obstructions such as protruding service connections, objects sticking into the pipe, pieces of broken pipe, and roots require special consideration and care so the camera will not become wedged in the pipe,
5. If the camera is out of position, a properly designed camera and skid should right itself,
6. A foggy or indistinct picture, after getting a sharp picture in the pipe, indicates that the viewport and possibly the optical lens have become fogged,
7. An accumulation of grease on the light head, and
8. Sewers flow more than half full and require a plug at the upper manhole.
9. Presence of explosive gas mixtures in sewer line.

5.43M A TV camera must *NEVER* be forced past an obstruction because if it becomes wedged tight, the line must be dug up to recover the camera.

5.43N When a TV camera encounters a bad joint that it cannot pass, the joint must be repaired before the remainder of the line can be televised. Another approach would be to pull the camera from the opposite direction towards the bad joint. Be sure your footage measurements are correct and that everyone understands what you did.

5.43O If the viewport is very dirty with grease or other surface debris after being under water, there are three possible procedures for clearing the viewport.

1. Back the camera up until it is under water and allow it to sit for a minute or so to allow debris to be floated off,
2. Open a fire hydrant and discharge water into the upstream manhole in an attempt to wash away the debris, and
3. Pull camera to downstream manhole, clean the viewport, and pull the camera back to where you wish to continue televising the line.

5.43P If a foggy or indistinct picture was observed shortly after the TV camera entered the pipe, try to determine what caused the problem and correct the situation. In this case, the glass in the lens was probably cold. Remove the camera from the pipe and try to warm the entire camera by placing it in a warm room, or behind or under a cardboard in the sunlight, or in a vehicle parked in the sun with the windows closed.

Answers to questions on page 223.

5.43Q Before turning in the television log sheet, every entry should be checked for readability, accuracy, and cleanliness.

5.43R The distance measured by the footage meter must be verified so all important distances recorded will be correct or can be corrected in order to help repair crews and future inspection crews.

5.43S The first act of the shut-down procedure is to turn off all power to the camera and light. Power must be off before anyone attempts to handle the camera or pull it out of the pipe. Shut off all switches *BEFORE* shutting down the generator to avoid lower power damage to certain components of the camera and monitor.

5.43T Be sure the light assembly has cooled to a level that it can be safely handled before the viewport cover is installed on the camera.

5.43U The electrical contacts at the end of the power cables are protected from debris and moisture by placing a special cap or plug over the end of the contacts before the cable is retrieved back up the line.

5.43V To clean the tag line and power cable while they are being rewound, use a piece of foam rubber or a felt pad. Don't use a cloth with threads because pieces can be torn loose and wrap around the cables. Even a leather glove is not safe because small single strands of cable can break and stick out, scratch your hand, and cause a serious infection.

Answers to questions on page 223.

5.44A To select closed circuit TV equipment, talk to other collection system operators and consider their experiences and recommendations to help make a decision. If possible, arrange for a demonstration of the equipment being considered for purchase.

Answers to questions on page 224.

5.45A A photograph can be made of a problem inside a pipe by photographing the video picture in the television monitor or by using 3D photography.

5.45B Only high-speed black and white film should be used to take photos of the video picture in the TV monitor.

5.45C The most popular camera used to take photos of the video picture is the polaroid.

5.45D Information attached to a photograph should include:

1. Date,
2. Identification of line,
3. Footage location of the scene in the picture, and
4. Log entry number (depends on record keeping system).

ANSWERS TO QUESTIONS IN LESSON 4

Answers to questions on page 232.

5.5A The purpose of smoke testing is to determine:

1. Source of entry to the collection system of surface waters,
2. Proof that buildings or residences are connected to a wastewater collection system,
3. Location of certain types of illegal connections,
4. Location of broken sewers, and
5. Location of lost manholes.

5.5B Equipment needed for a smoke testing operation includes:

1. Smoke blower unit,
2. Pipe plugs (mechanical or inflatable), and
3. Smoke bombs.

5.5C Before starting a smoke testing program, take the following precautions:

1. Warn the public in advance when and where smoke testing is planned,
2. Notify local fire and police departments,
3. Train all operators how to handle persons who discover smoke in their homes,
4. Prepare operators to respect the property and privacy of owners and occupants,
5. Discuss with city or agency attorney testing methods and possible adverse results, and
6. Inspect area to be tested.

5.5D Air is forced into the pipe system by a blower five or ten minutes in advance to achieve a flow of air through the pipe system.

5.5E Observers should look for smoke from

1. Roof vents,
2. Building foundations, especially where the house sewer passes under the foundation,
3. Drains from evaporation type coolers,
4. Yard drains,
5. Rain gutters, and
6. Inside buildings.

ANSWERS TO QUESTIONS IN LESSON 5

Answers to questions on page 233.

5.6A The purpose of dye testing is to determine if certain facilities or fixtures are connected to the wastewater collection system such as

1. Buildings that don't show smoke from vents during smoke tests,
2. Yard drains or storm drains, and
3. Internal or surface inflow.

5.6B The only equipment needed for the dye test is the dye which is available in either powder or tablet form.

Answers to questions on page 234.

5.7A The purpose of pipeline lamping is to determine if a section of pipe is straight and open or not.

5.7B No, lamping should not be used to locate sources of infiltration or other pipe problems that do not affect pipe alignment.

OBJECTIVE TEST

Chapter 5. INSPECTING AND TESTING COLLECTION SYSTEMS

TRUE-FALSE

1. Clothing worn during sewer repair work should be washed with the family laundry that night so it will be clean the next day.
    1. True
    2. False
2. Closed circuit television can be used to evaluate effectiveness of solutions and equipment in maintaining or correcting problem areas in sewers.
    1. True
    2. False
3. Common practice is to pull a TV camera from a downstream manhole to an upstream manhole.
    1. True
    2. False
4. Never touch a TV camera in a manhole unless all power has been switched off.
    1. True
    2. False
5. The local fire department must be thoroughly briefed on a smoke testing operation before it is started.
    1. True
    2. False

MULTIPLE CHOICE

6. Sewers may be tested for leaks by using
    1. Air.
    2. Ammonia.
    3. Chlorine.
    4. Smoke.
    5. Water.

7. Improper connections can be detected by
   1. Dye tests.
   2. Firemen.
   3. Policemen.
   4. Smoke tests.
   5. TV inspection.

8. Infiltration can be caused by
   1. Cracked pipes.
   2. Filtration pipes.
   3. Poor joints.
   4. Root intrusion.
   5. Sealed joints.

9. Items that must be examined when inspecting manholes include
   1. Cracks.
   2. Corrosion.
   3. Elevation of lid.
   4. Fit of lid.
   5. Shelf of manhole.

10. Hazards that may be encountered by a TV camera going through a sewer include
    1. Deep water that submerges the camera.
    2. Explosvie gases that could be ignited by heat from the head lamp.
    3. Fogging of optical lens.
    4. Grease on the head lamp.
    5. Offset joints.

11. Some of the advantages of a video tape recording system include
    1. Ability to see what's happening when camera is under water.
    2. Cheaper than a polaroid camera.
    3. Length and severity of defective areas can be recorded.
    4. Motion of infiltration flows is recorded.
    5. Opportunity for TV operator to play back tape of one sewer while televising another sewer.

12. After leaving a manhole, an operator should
    1. Change clothes and wash thoroughly before going home.
    2. Go straight home.
    3. Test for explosive gases and oxygen deficiency.
    4. Turn on the blower to ventilate the manhole.
    5. Use a deodorant.

13. Items that must be checked before entering a manhole include
    1. Atmosphere in manhole.
    2. Briefing on procedures.
    3. Equipment.
    4. Health of operator entering manhole.
    5. Wash down of manhole if necessary.

14. Infiltration can be controlled by
    1. Balling the sewer.
    2. Inserting plastic liners or plastic pipes in the sewers.
    3. Regulating flows in pipe.
    4. Repairing or replacing broken or cracked pipes.
    5. Sealing cracks and joints in pipes.

15. Roots in sewers causing stoppages can be positively identified as the source of the problem by
    1. Closed circuit television inspection.
    2. Dye tests.
    3. Observing trees growing over the sewer.
    4. Smoke tests.
    5. Water tests.

16. What items should be considered when purchasing a closed circuit television camera?
    1. Cost to tie into community's commercial cable TV system
    2. Experience of other nearby communities
    3. Recommendation of local TV appliance dealer
    4. Reputation of manufacturer
    5. Results from demonstration of equipment

17. What factors or items could cause a TV camera to become wedged in a sewer if the operator is not careful?
    1. Fair lead pulley
    2. Jumps or drops in the pipe
    3. Protruding taps
    4. Roots
    5. Saddles on sewers for service connections

18. What kind of information should be reported during a TV inspection of a sewer?
    1. Date
    2. Defects in pipe
    3. Distance from manhole to recorded observations
    4. Potential or existing types or causes of stoppages
    5. Quantity of water to flush sewer

19. Closed circuit television is used by wastewater collection system operators to
    1. Correct or verify "As-Built" plans.
    2. Evaluate effectiveness of sewer cleaning and clearing techniques.
    3. Identify causes of stoppages after they have been cleared.
    4. Look for sources of infiltration.
    5. Reveal causes of continuous maintenance problems at a specific location.

20. Newly constructed collection systems must be inspected to
    1. Be sure agency receives a functioning system from the contractor.
    2. Determine if contractor has complied with plans and specifications.
    3. Insure they will work properly before they attempt to convey wastewater.
    4. Look for sources of infiltration.
    5. Verify pipe materials.

21. Action taken as a result of a closed circuit television inspection of a collection system could include
    1. Assignment of operators and equipment for a preventive maintenance and repair program.
    2. Establish priorities for corrective work in old pipes on an "as needed" basis.
    3. Implementation of a root control program.
    4. Lamping the sewer.
    5. Notify supervisor home owners will not cooperate.

22. Types of defects that cause problems in wastewater collection systems include
    1. Design of facilities that hinder use of maintenance equipment.
    2. Improper grade of sewers.
    3. Joints poorly constructed.
    4. Structural failure of manholes.
    5. Use of material that fails under conditions existing in collection systems.

23. When conducting a closed circuit television inspection of a sewer
    1. Always pull camera from upstream manhole to downstream manhole.
    2. Attach proper skids to camera to place lens as close as possible to the top of pipe so camera won't go under water.
    3. Direct and divert traffic around operators and work area.
    4. Never inspect camera, connections and cables with the power on.
    5. Warn local residents that a TV camera will be in the neighborhood sewers.

24. While the TV camera is being pulled through the line, the
    1. Camera must never stop.
    2. Greater the drag on the cable, the harder the pull winch operator must pull.
    3. Operator must never stop looking at the picture on the monitor.
    4. Operator should be examining the plans of the next sewer to be televised.
    5. Progress of the camera should be stopped whenever communications are lost with other crew members.

25. After a pipe has been inspected by the TV camera described in this chapter,
    1. Clean camera, cables and equipment.
    2. Disconnect power cables and protect electrical contacts from debris and moisture.
    3. Install viewport cover on camera as soon as lamp assembly is cool.
    4. Remove camera from downstream manhole.
    5. First turn off all power to the camera and light.

END OF OBJECTIVE TEST

APPENDIX

5.9 CLOSED CIRCUIT TELEVISION EQUIPMENT DETAILS

To review and evaluate an existing closed circuit TV inspection program or to consider starting a new program, the following steps can help you decide whether to purchase or rent equipment and select a manufacturer or contractor.

1. Make a list of the uses of the TV inspection program and information you wish to gain from the program.
2. List the important components of the TV inspection equipment and compare the equipment of potential manufacturers and contractors.
3. Compare economics, manpower, experience of others, maintenance requirements, and actual demonstrations and then select the best type of TV inspection program for your agency.

5.91 Uses of Closed Circuit TV

5.911 Inspection

1. Examine work completed by contractors.
2. Examine taps installed by a plumber or by maintenance crews.
3. Find and pinpoint inflow/infiltration and estimate amounts.
4. Locate unrecorded and/or illegal taps such as industrial, storm water or surface drainage.

5.912 Maintenance

1. Examine sewer problem areas such as pipe or joint rupture, condition of service connections, leaks, obstructions, corrosion and pipe alignment.
2. Look at a sewer line to determine what type of cleaning equipment would best solve a problem such as roots, grease or grit deposits.
3. Determine if equipment selected did the desired maintenance or repair job and produced cost effective results.
4. Review jobs done by repair crews fixing cracked pipe.

5.913 Rehabilitation Tool

1. Grouting control inflow/infiltration (see Chapter 7, Section 7.6, Sealing Grout).
2. Slip lining — TV sewer prior to inserting a liner to look for protruding taps and severe misalignment conditions (see Chapter 10, "Sewer Rehabilitation").

5.92 Experience of Others and Observations from Demonstrations

One of the best ways to determine if a manufacturer can provide you with the TV equipment you need or if a contractor can provide you with the services you need, is to contact their previous clients. Talk to other collection system operators and consider their experiences and recommendations.

Always have the equipment manufacturers or contractors demonstrate their equipment. During the demonstration have the crews that will actually use the equipment try to use the equipment. Their comparisons of different equipment will be very valuable. If a contractor is demonstrating equipment, have the people who will use the results observe the demonstration and be sure they understand what is observed and what is recorded. Their comparison of the different contractors' ability to describe actual observations will be very helpful. If you are considering the purchase of TV equipment, try to rent the equipment first so you can evaluate the performance of the equipment and the results.

5.93 The Decision: Use a Contractor or Purchase Equipment

First the decision must be made whether to hire a contractor or to purchase closed circuit TV equipment. Important factors to evaluate include what needs to be televised, how long will it take, how much money is available and whether or not qualified operators are available to do the job.

The selection of a contractor or equipment manufacturer is usually based on the lowest qualified bidder. For this reason specifications must be carefully prepared and only qualified contractors or manufacturers allowed to submit bids. Recommendations and experiences of other agencies and the comments of persons participating in demonstrations should be considered when determining the qualifications of bidders.

5.94 Important Components of TV Inspection Equipment

Once the uses of a TV inspection program have been identified, the ability of the equipment of potential manufacturers and contractors to do the job can be compared. Important features of closed circuit television equipment that should be compared include:

5.941 Camera

1. Lighting requirements, inside pipe
2. Pressure rating in psi
3. Type of connectors
4. Horizontal resolution
5. Type of circuitry
6. Iris, focus, lens adjustments
7. Depth of field at various focal settings
8. Physical specifications — shock, vibration
9. Actual picture clarity

Television cameras for sewer line televising should contain selective features. To illustrate the type of information that should be obtained, the following list is provided:

1. Waterproof electrical and case assemblies to withstand pressure tests (external) up to 100 psi.
2. 600-line horizontal resolutions.
3. Synchronous crystal control.
4. 50 degree or greater wide-angle lens, maximum distortion not to exceed 2 percent.
5. Camera lens adjustments to be made through external means.
6. Camera viewport to be of optical grade quartz, not less than ⅜-inch thick.
7. Solid state electronic assembly, vidicon tube excepted, but with capacity to withstand three successive impacts of 25-Gs without damage.
8. Manufacturer to warrant camera (including vidicon tube) against defects in materials, parts, and workmanship for at least one year.
9. Manufacturer must provide adequate training for crew in field.

5.942 TV Cable

1. Tensile strength
2. Connectors
3. Length
4. Conductors, what kind, what size, how many

5.943 Video Monitor

1. Size of screen
2. Suited for mobile operation
3. Horizontal resolution
4. Video or RF

5.944 TV Cable Reel

1. Cantilever or axial mounted
2. Size
3. What type of rewind

5.945 Measure Meter

1. Accuracy
2. Placement of readout
3. Remote readout

5.946 System Control Unit

1. Protection circuits
2. Fuses
3. Circuitry — lights and camera
4. Input voltage, output voltage
5. Safety of unit

5.947 Light Head Assembly

1. Type bulbs required
2. Maintenance expected on unit
3. Lamp voltage

5.948 Skids and Tow Cables

1. Durability
2. Expected wear and tear
3. Serviceability
4. Pipe size range

5.949 Miscellaneous Items

1. Video input information devices
2. Manhole jacks
3. Surface rollers
4. Powerplants
5. Video tape equipment
6. Crew size

5.95 Economics

1. Initial cost and estimated life of TV unit
2. Expected maintenance costs
3. Crew requirements and labor costs
4. Expected production (feet of sewer televised per day and also feet televised per year)
5. Cost per foot (overall) of inspection
   a. Equipment Costs,

   $$\$/\text{year} = \frac{\text{Initial Cost, \$}}{\text{Estimated Life of Unit, yr}}$$

   b. Maintenance Costs, $/year
   c. Labor Costs, $/year
   d. Total Cost to Operate TV unit, $/yr = (a) + (b) + (c)
   e. Costs, $/ft =

   $$\frac{\text{(d) Total Cost, \$/yr}}{\text{(4) Expected Production, ft/yr}}$$

5.10 CODES FOR TV INSPECTION, DEFECTS AND ACTIONS/RESPONSES

Excellent publications containing photographs illustrating standard sewer defects and terminology have been developed by the Water Research Centre, PO Box 85, Frankland Road, Blagrove, Swindon, Wiltshire, 5H5 8YR, ENGLAND.

The following codes were developed by Rich Cunningham, City of San Francisco, as an assignment of the Water Pollution Control Federation's Wastewater Collection System Committee. "Un" refers to unit of measurement (lf, lineal feet of brick de-mortared, but still intact).

5.11 ADDITIONAL TV INSPECTION EQUIPMENT INFORMATION

An electric powered remote control winch can be used at the far manhole to replace the hand winch. This same type winch can also be used as the "retrieve" or "tag winch" at the truck as shown in Figure 5.22.

Lateral sealing system: This lateral sealing device works from a tool very similar to a joint packer. The system is capable of sealing a service lateral against infiltration for a distance of three to eight feet from the main line sewer. This equipment is shown in Figure 5.23.

Lateral inspection camera: A very small diameter inspection camera capable of traveling up service laterals for approximately thirty feet. These cameras can be launched from a packer like device from the main sewer line. See Figures 5.23, 5.24 and 5.25.

Self-propelled camera transporter: An electric motor driven carrier assembly that will transport a closed circuit television camera into a sewer line without the need of a pull winch. This device is extremely useful when televising to a "dead end" pipe or into a highly congested intersection where the stationing of equipment or workers over a sewer manhole would present a safety hazard. See Figure 5.26.

Portable TV system for small diameter pipe: A totally portable closed circuit TV system that can be used in small diameter pipe (4" and 6") and will negotiate multiple bends up to 90 degrees. The camera can be inserted into the lines through cleanouts or other openings. See Figures 5.27 and 5.28.

Modular TV inspection system: A very compact portable TV inspection system that can easily fit into a pick-up truck, van or trailer. This type of unit would be sufficient for an agency that did not have continual need for a TV system. See Figure 5.29.

TV operator's control panel: In a van, trailer or step-van unit, all the necessary controls are grouped together in a separate air conditioned room. The TV operator has full control of the camera's movement once it is placed in the sewer line. See Figure 5.30.

Electronic data recording system: An alpha-numerical keyboard that allows all job data to be recorded on the video tape. See Figure 5.31.

Television datalog unit: A specially designed keyboard that can enter pipe condition information quickly onto a data cartridge. Log sheets can be printed out, work orders can be generated and rehabilitation cost comparison can be evaluated. See Figure 5.32.

Code	Description	Un	Is this Okay? Y	N
INSPECTION INFORMATION				
BDM	Brick de-mortared, but still intact	lf	☐	☐
BMS	Brick missing, backfill showing	sf	☐	☐
CAB	Camera blocked and unable to proceed further	ea	☐	☐
CAS	Camera submerged	ea	☐	☐
CAV	Cavity outside the line	ea	☐	☐
CKL	Cracking, lateral, i.e. parallel to the direction of the flow	lf	☐	☐
CKT	Cracking, transv., i.e., across the direction of the flow	lf	☐	☐
COR	Corrosion, sulfide	lf	☐	☐
CRS	Crushed	lf	☐	☐
DAM	Damage, other causes, such as chemical attack	lf	☐	☐
DEB	Debris accumulated in invert	lf	☐	☐
DIS	Distorted shape, loss of concentricity	lf	☐	☐
DWO	Dry weather overflow	ea	☐	☐
FDP	Flow depth	in	☐	☐
FIL	Infiltration flow rate	gm	☐	☐
FLO	Inflow rate	gm	☐	☐
GRS	Grease accumulation	lf	☐	☐
INV	Invert damage, such as abrasion	sf	☐	☐
JOI	Joint offset	in	☐	☐
JOP	Joint separated longitudinally	in	☐	☐
LEA	Leaking observed at deformed or missing seal	ea	☐	☐
MDJ	Mineral deposit at joint	ea	☐	☐
MHS	MH overflow or surcharging	ea	☐	☐
MIN	Mineral deposits or scaling on pipe wall	lf	☐	☐
MLS	Main line surcharging	ea	☐	☐
NFT	Inflow of tidewater	gm	☐	☐
ODR	Odor complaint	ea	☐	☐
OTH	Other	ea	☐	☐
RAT	Rat infestation	ea	☐	☐
ROA	Roach infestation	ea	☐	☐
ROO	Root intrusion	lf	☐	☐
RUO	Mechanism rusted in open position	ea	☐	☐
RUS	Mechanism rusted in shut position	ea	☐	☐
SAG	Sagged line	lf	☐	☐
SDM	Structural damage to manhole, etc.	sf	☐	☐
SER	Serviceable or okay	ea	☐	☐
SPM	Part(s) missing from structure e.g. rungs, gaskets	ea	☐	☐
SLS	Service lateral surcharging	ea	☐	☐
SPL	Spalling	lf	☐	☐
TA1	Abandoned tap 12-3 o'clock position when seen from TV	ea	☐	☐
TA2	Abandoned tap 3-6 o'clock position when seen from TV	ea	☐	☐
TA3	Abandoned tap 6-9 o'clock position when seen from TV	ea	☐	☐
TA4	Abandoned tap 9-12 o'clock position when seen from TV	ea	☐	☐
TI1	Tap intruding 12-3 o'clock position when seen from TV	ea	☐	☐
TI2	Tap intruding 3-6 o'clock position when seen from TV	ea	☐	☐
TI3	Tap intruding 6-9 o'clock position when seen from TV	ea	☐	☐
TI4	Tap intruding 9-12 o'clock position when seen from TV	ea	☐	☐
TP1	Tap: 12-3 o'clock position when seen from TV	ea	☐	☐
TP2	Tap: 3-6 o'clock position when seen from TV	ea	☐	☐
TP3	Tap: 6-9 o'clock position when seen from TV	ea	☐	☐
TP4	Tap: 9-12 o'clock position when seen from TV	ea	☐	☐
TR1	Tap w/roots 12-3 o'clock position when seen from TV	ea	☐	☐
TR2	Tap w/roots 3-6 o'clock position when seen from TV	ea	☐	☐
TR3	Tap w/roots 6-9 o'clock position when seen from TV	ea	☐	☐
TR4	Tap w/roots 9-12 o'clock position when seen from TV	ea	☐	☐
VRM	Vermin, general	ea	☐	☐
WWO	Wet weather overflow	ea	☐	☐
FIELD INFORMATION				
BMB	Basement or cellar drain backed-up	ea	☐	☐
CBO	Catchbasin/Storm drain grate off grate is missing	ea	☐	☐
FIELD INFORMATION (continued)				
CCB	Catchbasin/Storm drain culvert pipe is blocked	ea	☐	☐
CFL	Catchbasin/Storm drain full of debris	ea	☐	☐
CGB	Catchbasin/Storm drain grate covered w/debris; can't drain	ea	☐	☐
CNA	Crew needs assistance from another crew	ea	☐	☐
CNI	Contract work needs inspection at the job site	lf	☐	☐
CON	Construction job in progress at site of complaint	ea	☐	☐
DEP	Depression or void in road/street	sf	☐	☐
DEW	De-watering of jobsite is required	gl	☐	☐
INS	Inspection by service crew is needed	ea	☐	☐
LOS	Lost article is reported in manhole, cb, or st. drain	ea	☐	☐
MAG	Manhole above grade	ea	☐	☐
MBG	Manhole below grade	ea	☐	☐
MBU	Manhole buried or not visible	ea	☐	☐
MHO	Manhole is open/cover gone	ea	☐	☐
MHP	Manhole requires paving around rim	ea	☐	☐
MLB	Main line blocked	ea	☐	☐
MLS	Main line surcharging	ea	☐	☐
MNC	Manhole noise complaint	ea	☐	☐
ODR	Odor complaint	ea	☐	☐
ORP	Owner of property is responsible for problem	ea	☐	☐
OTR	Other type problem	ea	☐	☐
PSP	Pump/P.S. problem	ea	☐	☐
SLB	Service lateral blocked	ea	☐	☐
SLS	Service lateral surcharged	ea	☐	☐
SSR	Scheduled service is required to be performed	ea	☐	☐
SUB	Sump blocked, leading to interceptor	ea	☐	☐
TRP	Trench requires paving	sf	☐	☐
UNK	Unknown situation	ea	☐	☐
WTR	Water main broken	ea	☐	☐
ACTION/RESPONSE				
AGI	Aboveground inspection performed	ea	☐	☐
AST	Assist a crew requiring further help	ea	☐	☐
BAL	Balling style cleaning	lf	☐	☐
BGI	Below ground inspection	ea	☐	☐
BKF	Backfill, tamp down or jet down for compaction	cy	☐	☐
BUC	Bucket machine cleaning	lf	☐	☐
BYP	Bypass: plug line upstream and pump around to downstream	lf	☐	☐
CLG	Clean grate(s) of pump station or comminutor, etc.	ea	☐	☐
CLM	Clam bucket removal of debris	cy	☐	☐
CON	Contract work is required to resolve the problem	ea	☐	☐
DCR	Dust for roaches	sf	☐	☐
DRG	Dredge/dragline cleaning	cy	☐	☐
DYE	Dye test	ea	☐	☐
EXC	Excavation	lf	☐	☐
FLU	Flush line with non-pressurized water	ea	☐	☐
GRT	Grout seal	sf	☐	☐
GSK	Gasket seal/reseal joints in manhole or line	ea	☐	☐
IMB	Install manhole base	ea	☐	☐
INC	Inspection done	ea	☐	☐
IST	Insituform installation performed	lf	☐	☐
JET	Hydrojet clean	lf	☐	☐
KIT	Kiting style cleaning	lf	☐	☐
LIN	Repair/patch line	lf	☐	☐
LNI	Line, new installation	lf	☐	☐
LDO	Locate dry weather overflow	ea	☐	☐
LWO	Locate wet weather overflow	ea	☐	☐
MHC	Manhole channelization	ea	☐	☐
MHI	Manhole installation	ea	☐	☐

Code	Description	Un	Is this Okay? Y	N
ACTION/RESPONSE (continued)				
MHI	Manhole installation	ea	☐	☐
MLA	Main line air pressure test	ea	☐	☐
MOS	Mosquito control	ea	☐	☐
MRK	Mark street surface for dig-up	ea	☐	☐
OTA	Other resp./action	ea	☐	☐
OWN	Owner or other responsible party was notified	ea	☐	☐
PAD	Quiet cover/grate that causes noise	ea	☐	☐
PAV	Pave/repace street surface	sf	☐	☐
PLN	Plunge to unblock with mechanical plunger	ea	☐	☐
PLS	Plaster/Re-plaster brick or mortar	sf	☐	☐
RAT	Bait for rats	ea	☐	☐
REP	Replace. cover/lid on manhole or drain	ea	☐	☐
RFC	Replace manhold frame and cover	ea	☐	☐
ROD	Mechanical rodding	lf	☐	☐

Code	Description		Is this Okay? Y	N
ACTION/RESPONSE (continued)				
RTC	Root cutting with mechanical root shears	lf	☐	☐
RTF	Root foaming with chemical herbicide	lf	☐	☐
RTS	Root soaking with chemical herbicide	lf	☐	☐
SCO	Scooter cleaning	lf	☐	☐
SLA	Service lateral air pressure test	ea	☐	☐
SLC	Service lateral to main line connection (tap-in)	ea	☐	☐
SLP	Slip line installation	lf	☐	☐
SMO	Smoke test	ea	☐	☐
SNK	Snake to unblock stoppage in line	lf	☐	☐
STI	Structure, new installation	ea	☐	☐
STR	Structure, repair	ea	☐	☐
STV	String tv line	lf	☐	☐
TAP	Install tap/saddle	ea	☐	☐
TVI	Television inspection	lf	☐	☐
VAC	Suction debris out	ea	☐	☐

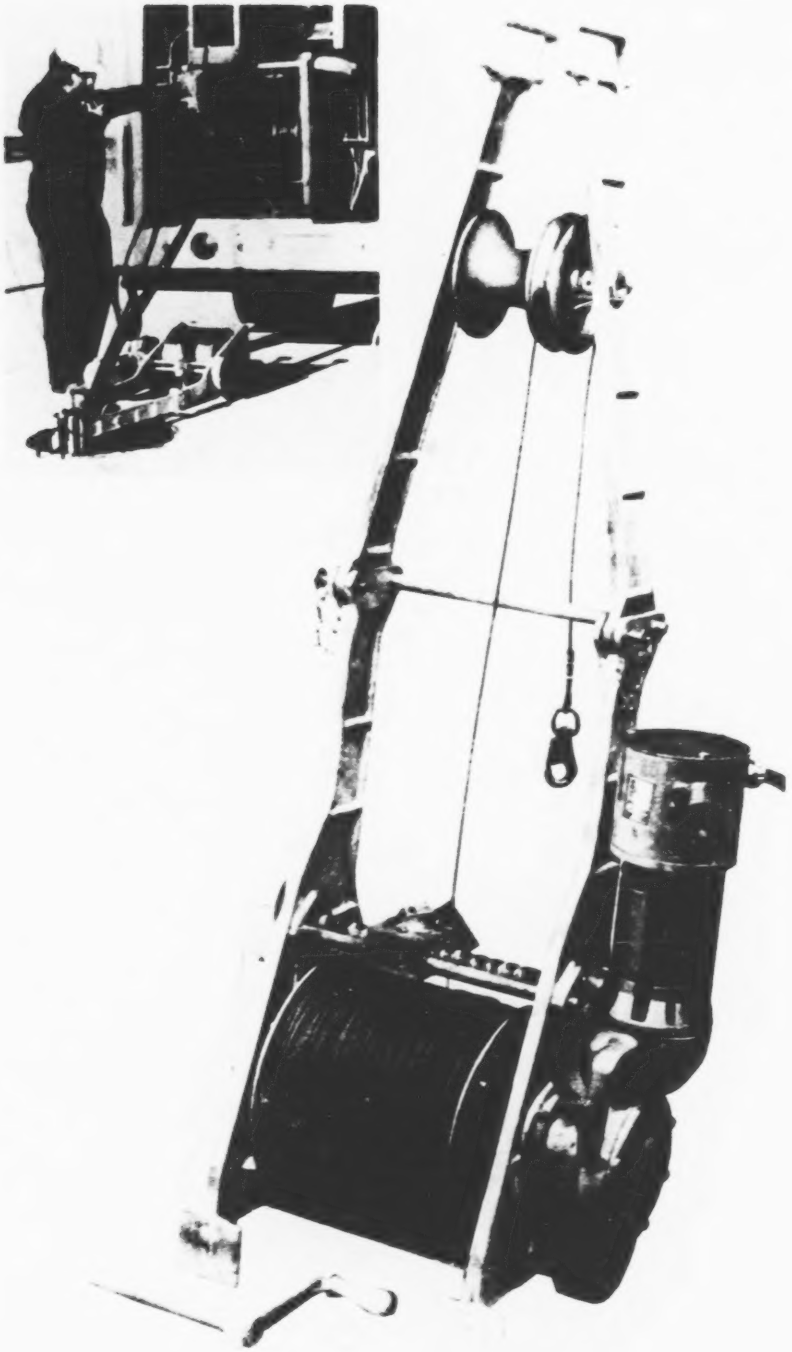
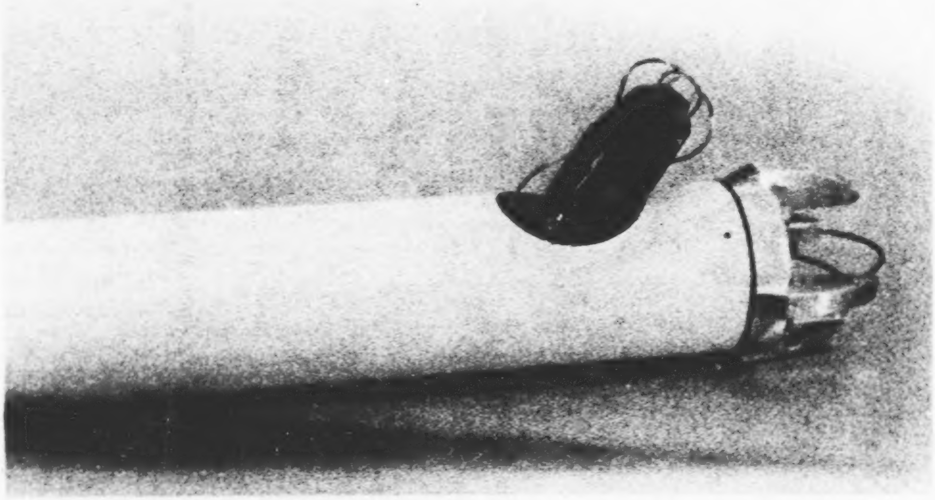
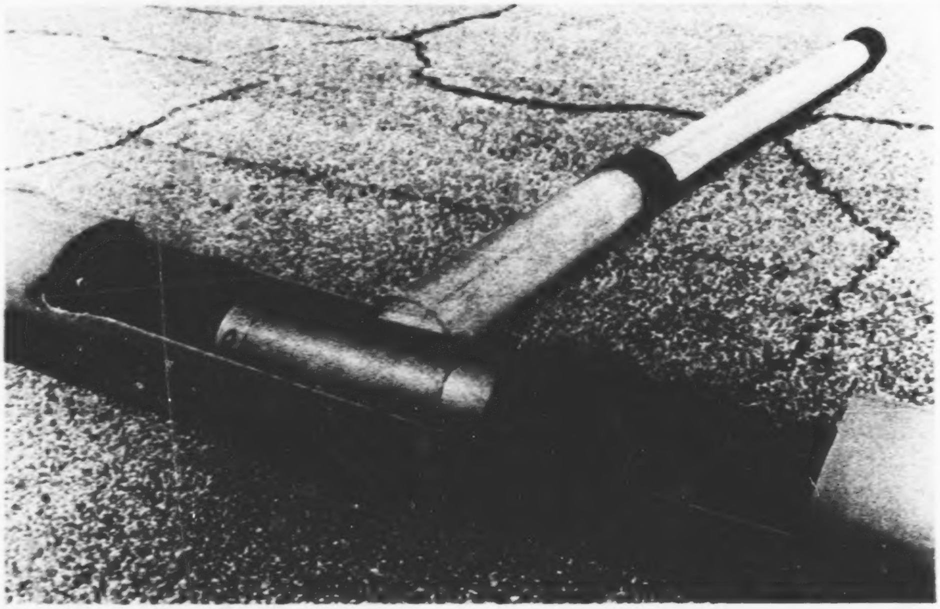


Fig. 5.22 Electric powered remote controlled winch

(Courtesy of CUES)

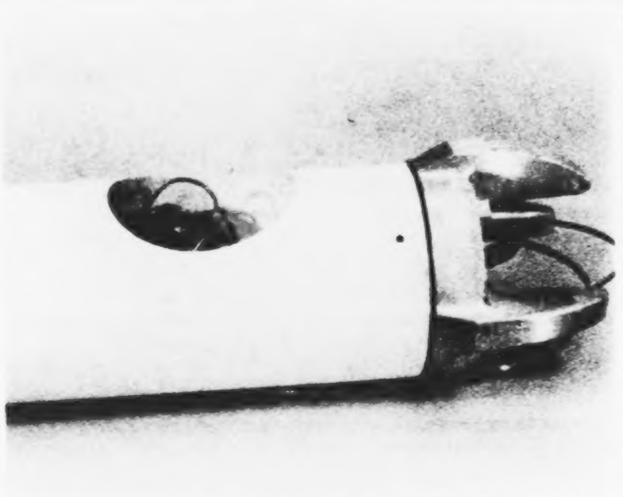


Lateral Inspection Camera

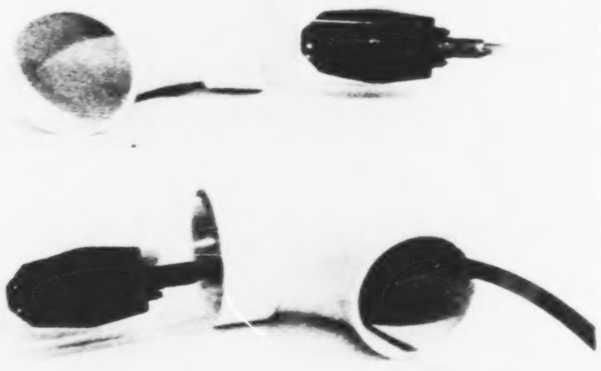


Lateral Sealing System

Fig. 5.23 Lateral sealing system
(Courtesy of CUES)



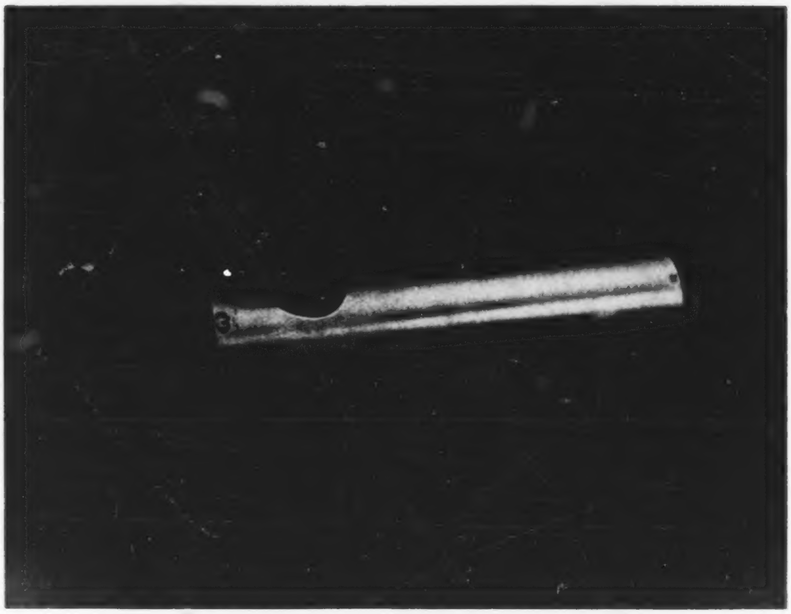
The Lateral Inspection Camera is launched from the mainline into the lateral.



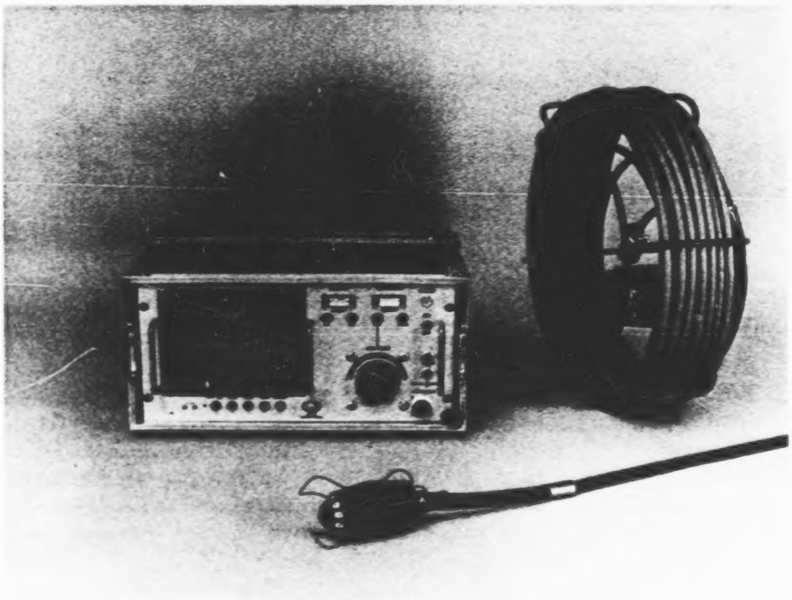
The small diameter Lateral Camera negotiates 90° bends in 4 inch diameter pipe.

Fig. 5.24 Lateral inspection TV camera

(Courtesy of CUES)



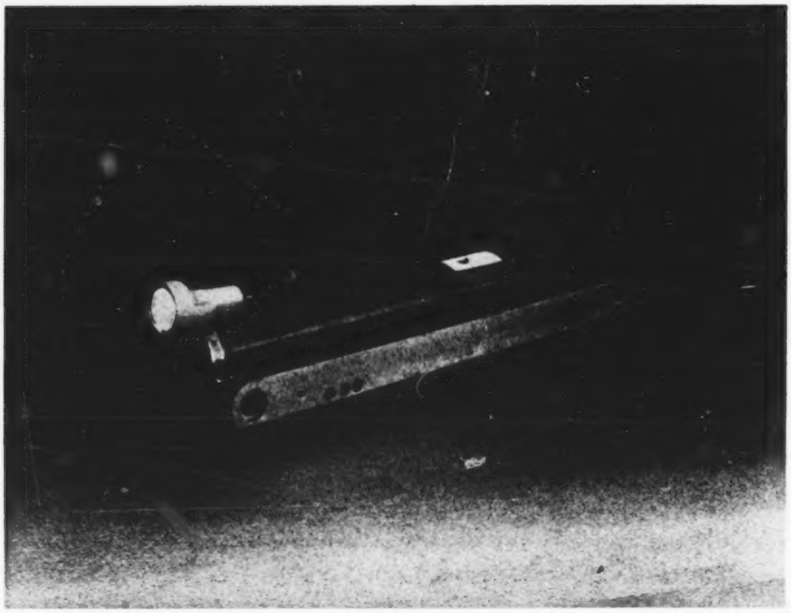
Small diameter sewer inspection camera and launcher
used to inspect service lines from main line.
Camera can be pushed 30 feet up the service line.



Mini scout camera system for
4-inch and 6-inch service line inspections.

Fig. 5.25 Mini scout camera system for 4-inch and 6-inch service inspections

(Courtesy of CUES)



Camera transporter designed to carry standard three-inch camera through 6-inch to 15-inch diameter sewer lines

Fig. 5.26 Self-propelled camera transporter
(Courtesy of CUES)

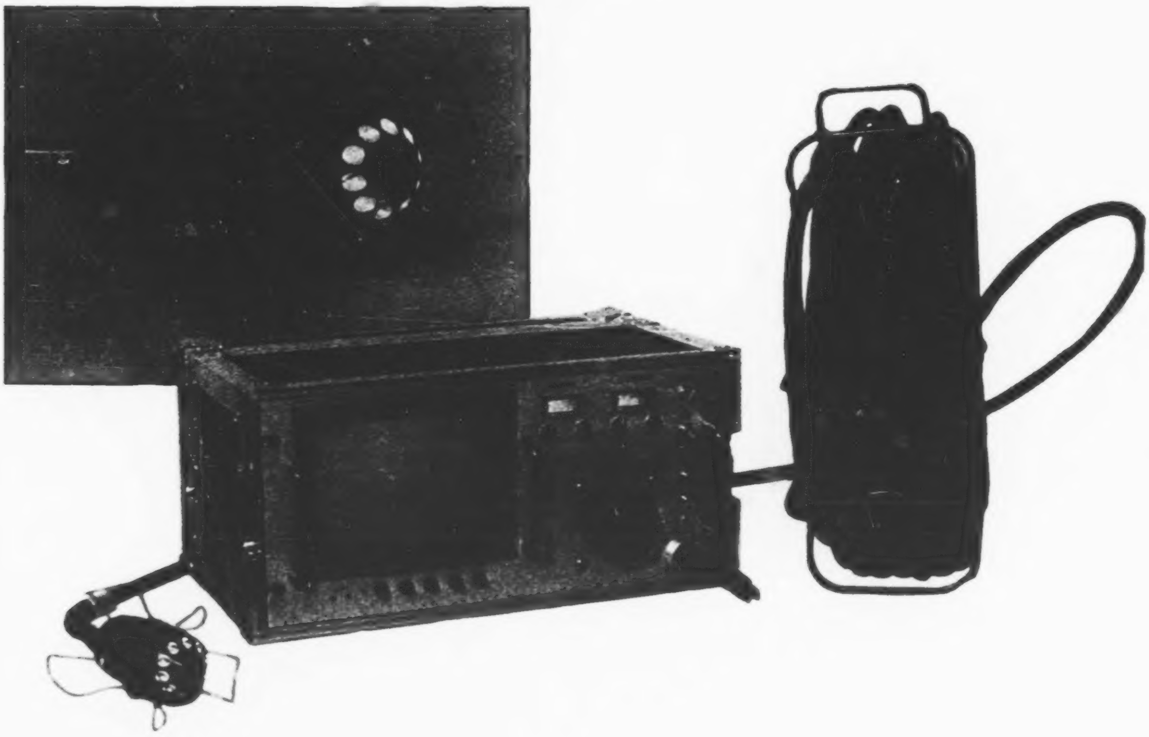
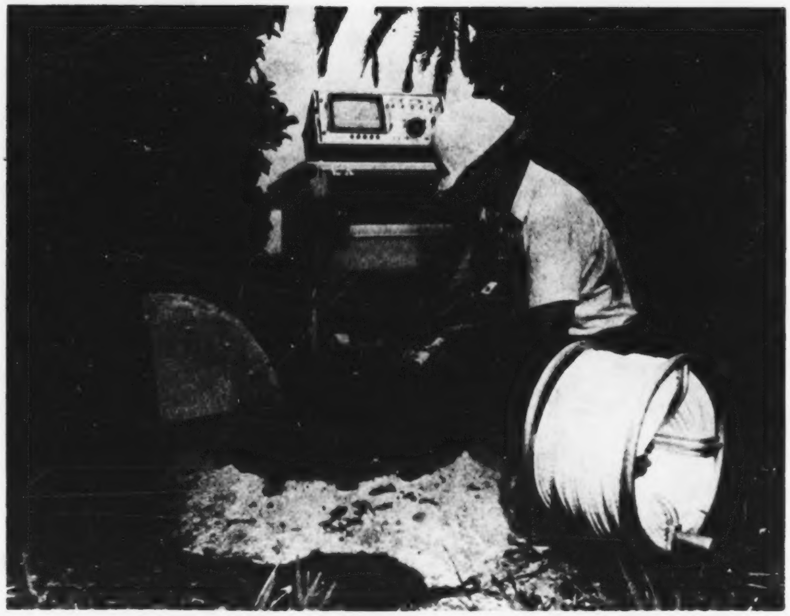
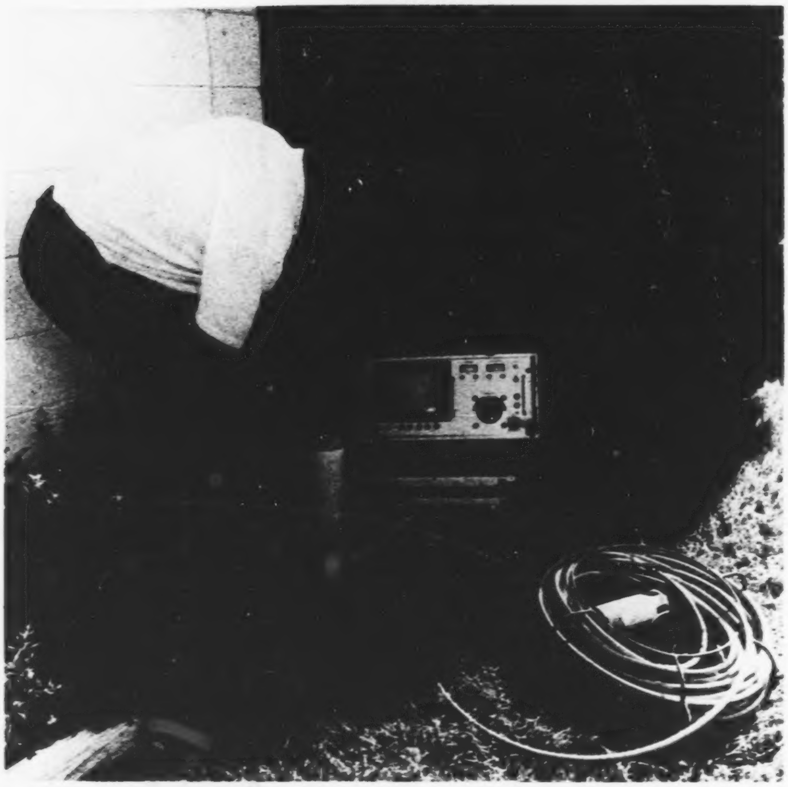


Fig. 5.27 Portable TV system for small diameter pipe
(Courtesy of CUES)



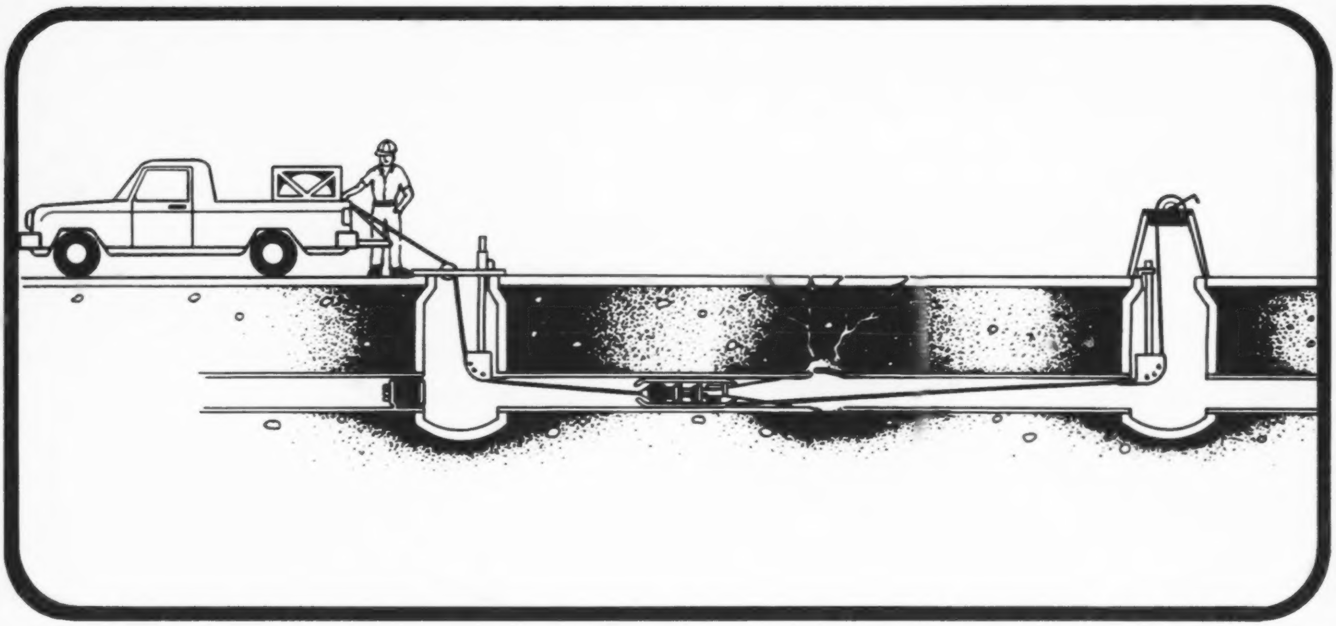
Portable TV system for hard access locations



Portable TV camera entering cleanout for lateral inspection

Fig. 5.28 Applications of portable TV system in difficult to access locations

(Courtesy of CUES)



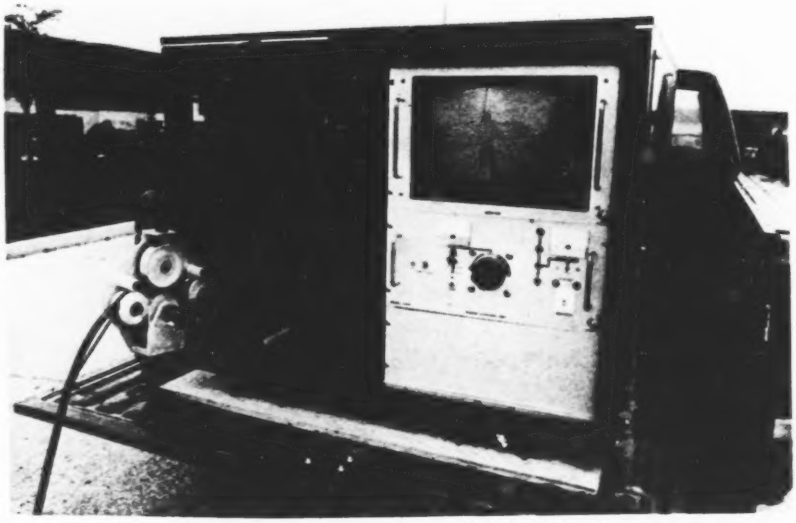


Fig. 5.29 Modular TV inspection system
(Courtesy of CUES)

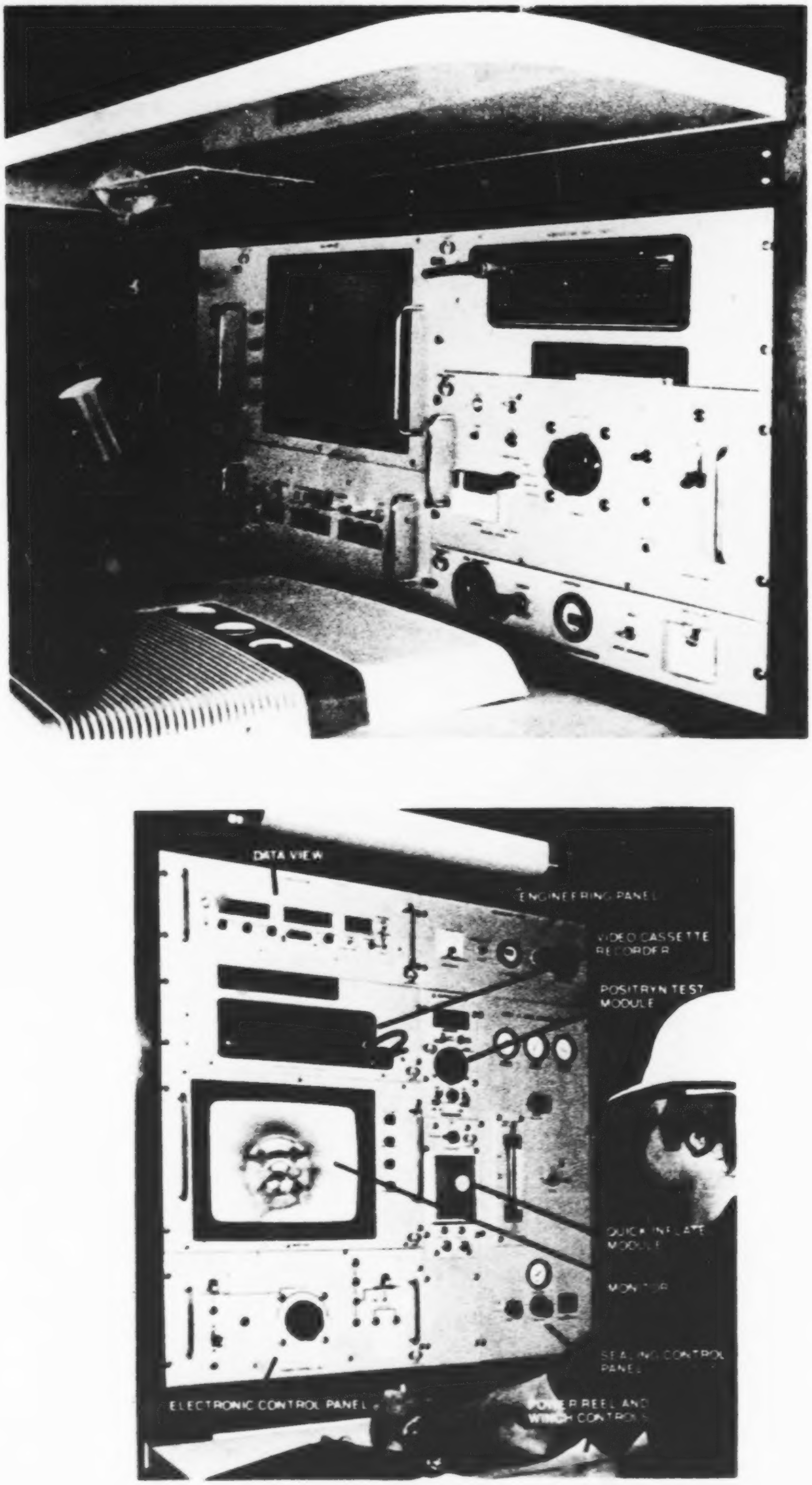
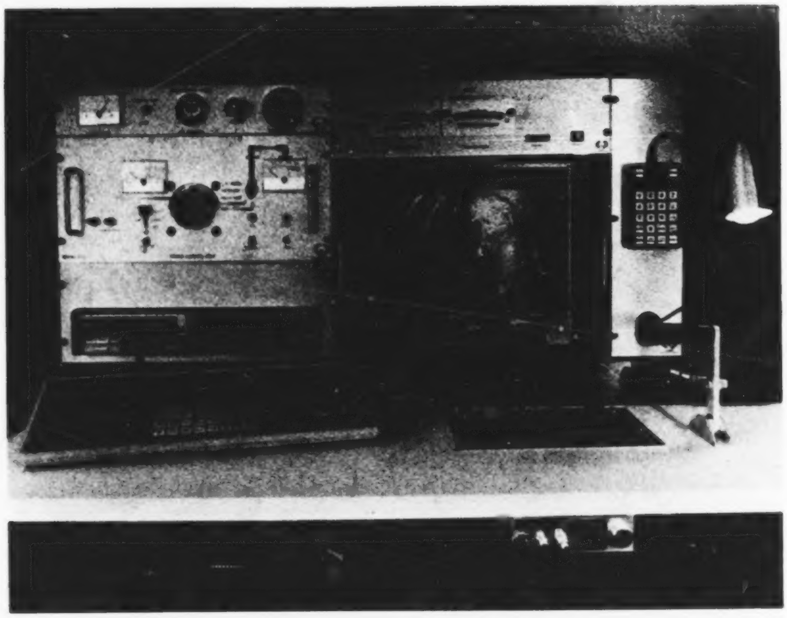
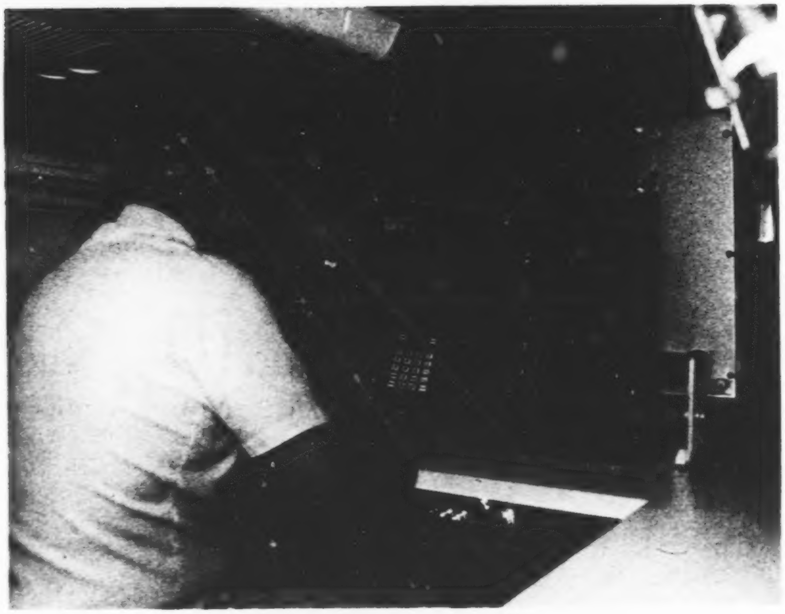

DATA VIEW
ENGINEERING PANEL
VIDEO CASSETTE RECORDER
POSITRYN TEST MODULE
QUICK INFLATE MODULE
MONITOR
SEALING CONTROL PANEL
ELECTRONIC CONTROL PANEL
POWER REEL AND WINCH CONTROLS

Fig. 5.30 TV operator's control panel
(Courtesy of CUES)

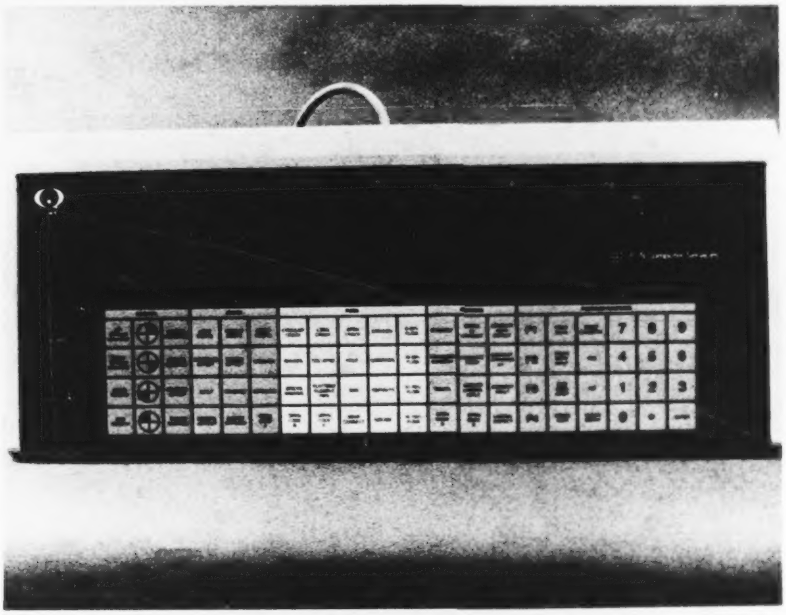


Television inspection van control panel

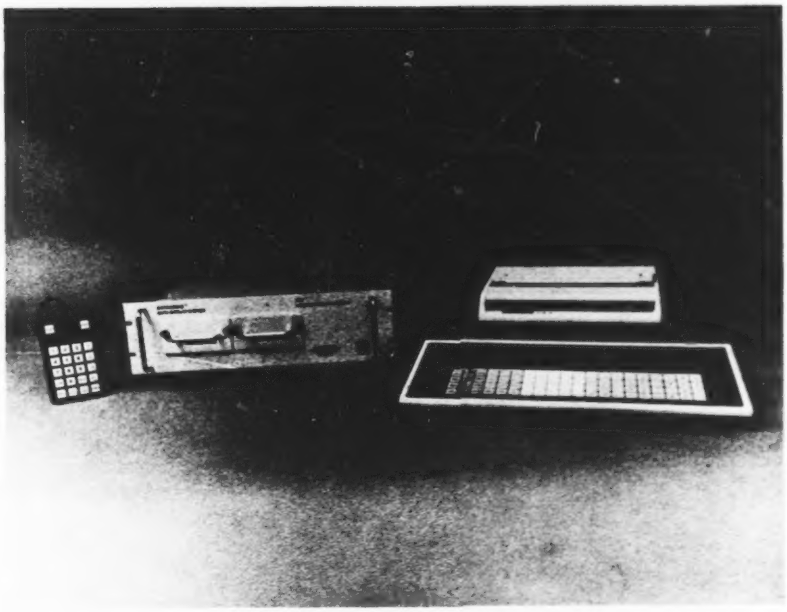


Keypad for entering inspection data on TV monitor.
Information is recorded on video tape.

Fig. 5.31 Electronic data recording system
(Courtesy of CUES)



Television datalog unit keyboard for automatically recording observations of line inspections.



Dataview/television datalog unit with keypad, keyboard and printer for recording observations of line inspections.

Fig. 5.32 Television datalog unit
(Courtesy of CUES)

CHAPTER 6

PIPELINE CLEANING AND MAINTENANCE METHODS

by

Dallas Hughes

Revised by

Bob Hiler

TABLE OF CONTENTS

Chapter 6. Pipeline Cleaning and Maintenance Methods

Page

OBJECTIVES 260

GLOSSARY 261

LESSON 1

6.1 How to Identify Problems and Select Solutions 264

- 6.11 Objectives of a Sewer Cleaning and Maintenance Program 264
- 6.12 Identification of Problem 264
  - 6.121 Types of Stoppages 264
  - 6.122 Identifying Causes of Stoppages and Problems 265
- 6.13 Methods for Cleaning and Maintaining Sewers 265
- 6.14 Selection of Solution to Problem 268
- 6.15 Equipment Required for Removing Stoppages and Cleaning Sewers 268
  - 6.151 Rodding 268
  - 6.152 Sewer Ball or Tire 268
  - 6.153 High Velocity Cleaner 268
  - 6.154 Bucket Machine 268
  - 6.155 Kite or Bag 268
  - 6.156 Scooter 269
  - 6.157 Flushing 269
  - 6.158 Scraper 269
- 6.16 Summary of Solutions 269
- 6.17 Work Assignment 270
- 6.18 Records 270
- 6.19 Notify Wastewater Treatment Plant 270

LESSON 2

6.2 Hydraulic Cleaning 273
  6.21 Balling 273
    6.211 Manpower and Equipment 273
    6.212 Equipment Set Up 282
    6.213 Cleaning Operation 282
    6.214 Precautions and Safety 287
    6.215 Records 287
    6.216 Summary 287
  6.22 High Velocity Cleaning Machines 287
    6.221 Manpower and Equipment 288
    6.222 Equipment Set Up 292
    6.223 Cleaning Operation 292
    6.224 Precautions and Safety 293
    6.225 Records 294
  6.23 Flushing 294
    6.231 Manpower and Equipment 294
    6.232 Equipment Set Up and Flushing 296
    6.233 Precautions and Safety 296
    6.234 Records 297
    6.235 Summary 297
  6.24 Scooters 297
    6.241 Manpower and Equipment 301
    6.242 Equipment Set Up 301
    6.243 Cleaning Operation 302
    6.244 Precautions and Safety 303
    6.245 Records 303
  6.25 Kites, Bags and Poly Pigs 303

LESSON 3

6.3 Mechanical Cleaning 306
  6.31 Power Bucket Machines 306
    6.311 Use of Power Bucket Machines 306
    6.312 Manpower and Equipment 308
    6.313 Equipment Set Up 314
    6.314 Operation 315
    6.315 Precautions and Safety 316
    6.316 Records 317

- 6.32 Power Rodders 317
  - 6.321 Uses of Power Rodders 317
  - 6.322 Classification 319
  - 6.323 Manpower and Equipment 320
  - 6.324 Equipment Set Up 325
  - 6.325 Tool Selection and Operation 325
  - 6.326 Recovery of Broken Rods 327
  - 6.327 Precautions and Safety 327
  - 6.328 Maintenance of Rods and Equipment 328
  - 6.329 Records 328
- 6.33 Hand Rods 329
  - 6.331 Manpower and Equipment 329
  - 6.332 Equipment Set Up 329
  - 6.333 Operation 331
  - 6.334 Precautions and Safety 331
  - 6.335 Records 332

LESSON 4

- **6.4** Cleaning Equipment Maintenance 333
  - 6.41 Need for Cleaning Equipment Maintenance 333
    - 6.411 Objective of Cleaning Equipment Maintenance 333
    - 6.412 Who is Responsible? 333
  - 6.42 Bucket Machine Maintenance 333
    - 6.421 Maintenance Tools 333
    - 6.422 Maintenance Procedures 333
  - 6.43 Rodding Machine Maintenance 334
    - 6.431 Maintenance Tools 334
    - 6.432 Sectional Rodder 334
    - 6.433 Continuous Rodder 335
    - 6.434 Hydraulic Unit on Rodding Machine 335
  - 6.44 High Velocity Cleaner Maintenance 335
    - 6.441 Maintenance Tools 335
    - 6.442 Continuous Considerations 335
    - 6.443 Daily 336
    - 6.444 Cold Weather Maintenance 336
  - 6.45 Equipment Engines 336

LESSON 5

6.5 Chemicals 338

- 6.51 Uses of Chemicals 338
- 6.52 How to Select Chemicals 338
  - 6.521 Words of Caution 338
  - 6.522 A Selection Procedure 339
- 6.53 Roots 340
  - 6.531 Causes of Root Problems 340
  - 6.532 Information Needed from Vendor or Manufacturer 340
  - 6.533 Application (flooding, spraying and foaming) 341
  - 6.534 Evaluation 341
  - 6.535 Safety Precautions 342
  - 6.536 Other Methods of Root Control 342
  - 6.537 Additional Reading 342
- 6.54 Grease 342
- 6.55 Odors 343
  - 6.551 Masking Agents 343
  - 6.552 Information Needed from Manufacturer 344
  - 6.553 Application of Masking Agents 344
  - 6.554 Evaluation 344
  - 6.555 Measurement of Odors 344
- 6.56 Corrosion 344
- 6.57 Rodents and Insects 344

6.6 Hydrogen Sulfide Control 345

- 6.61 Why Control Hydrogen Sulfide 345
- 6.62 How is Hydrogen Sulfide Produced? 345
- 6.63 Control of Hydrogen Sulfide 345
- 6.64 Collection System Maintenance and the Treatment Plant 347
- 6.65 Chemical Control of Hydrogen Sulfide 347
  - 6.651 Chlorine (Cl_2) 348
  - 6.652 Hydrogen Peroxide (H_2O_2) 348
  - 6.653 Pure Oxygen (O_2) 349
  - 6.654 Air 349
  - 6.655 Lime ($Ca(OH)_2$) 349
  - 6.656 Sodium Hydroxide (NaOH) 349
  - 6.657 Other Chemicals 350
- 6.66 Summary 350

SUGGESTED ANSWERS 352

OBJECTIVE TEST 358

OBJECTIVES

Chapter 6. PIPELINE CLEANING AND MAINTENANCE METHODS

After completion of Chapter 6 you should be able to do the following:

1. Identify types and causes of sewer stoppages,
2. Select proper methods to clear stoppages and clean sewers,
3. Determine equipment and manpower requirements for various sewer clearing and cleaning methods,
4. Set up sewer clearing and cleaning equipment safely and properly,
5. Operate and maintain sewer clearing and cleaning equipment safely and effectively,
6. Clean sewers without flooding homes and basements,
7. Record essential data regarding clearing and cleaning operations,
8. Direct the following clearing and cleaning operations:
   a. Balling,
   b. High velocity cleaners,
   c. Flushing,
   d. Sewer scooters
   e. Bucket machines,
   f. Power rodders, and
   g. Hand rods.
9. Establish a preventive maintenance program for sewer clearing and cleaning equipment, and
10. Develop a program to control odors and corrosion from hydrogen sulfide.

GLOSSARY

Chapter 6. PIPELINE CLEANING AND MAINTENANCE METHODS

AIR GAP AIR GAP

An open vertical drop, or vertical empty space, between a drinking (potable) water supply and the point of use. This gap prevents back siphonage because there is no way wastewater can reach the drinking water. Air gap devices are used to provide adequate space above the top of a manhole and the end of the hose from the fire hydrant. This gap insures that no wastewater will flow out the top of a manhole, reach the end of the hose from a fire hydrant, and be sucked back up to the hose to the water supply.

BALLING BALLING

A method of hydraulically cleaning a sewer or storm drain by using the pressure of a water head to create a high cleansing velocity of water around the ball. In normal operation, the ball is restrained by a cable while water washes past the ball at high velocity. Special sewer cleaning balls have an outside tread that causes them to spin or rotate, resulting in a "scrubbing" action of the flowing water along the pipe wall.

BARREL BARREL

(1) The cylindrical part of a pipe that has a bell on one end.

(2) The cylindrical part of a manhole between the cone at the top and the shelf at the bottom.

BLOCKAGE BLOCKAGE

(1) Partial or complete interruption of flow as a result of some obstruction in a sewer.

(2) When a collection system becomes plugged and the flow backs up, it is said to have a "blockage." Commonly called a STOPPAGE.

BUCKET BUCKET

(1) A special device designed to be pulled along a sewer for the removal of debris from the sewer. The bucket has one end open with the opposite end having a set of jaws. When pulled from the jaw end, the jaws are automatically opened. When pulled from the other end, the jaws close. In operation, the bucket is pulled into the debris from the jaw end and to a point where some of the debris has been forced into the bucket. The bucket is then pulled out of the sewer from the other end, causing the jaws to close and retain the debris. Once removed from the manhole, the bucket is emptied and the process repeated.

(2) A conventional bail is used in BUCKETING OUT.

BUCKET BAIL BUCKET BAIL

The pulling handle on a bucket machine.

BUCKET MACHINE BUCKET MACHINE

A powered winch machine designed for operation over a manhole. The machine controls the travel of buckets used to clean sewers.

BUCKETING OUT BUCKETING OUT

An expression used to describe removal of debris from a manhole with a pail on a rope. In balling or high-velocity cleaning of sewers, debris is washed into the downstream manhole. Removal of this debris by scooping it into pails and hauling debris out is termed "bucketing out."

FLUSHING FLUSHING

The removal of deposits of material which have lodged in sewers because of inadequate velocity of flows. Water is discharged into the sewers at such rates that the larger flow and higher velocities are sufficient to remove the material.

HAND ROD HAND ROD

A sewer rod that can be inserted manually (by hand) into a sewer to clear a stoppage or to prevent a stoppage from developing.

HIGH VELOCITY CLEANER HIGH VELOCITY CLEANER

A machine designed to remove grease and debris from the smaller diameter sewer pipes with jets of high velocity water. Also called a "Jet Cleaner," "Jet Rodder," "Hydraulic Cleaner," or "High Pressure Cleaner."

HYDRAULIC CLEANING HYDRAULIC CLEANING

Cleaning pipe with water under enough pressure to produce high water velocities.

(1) Using a high velocity cleaner.
(2) Using a ball, tire, kite or similar sewer-cleaning device.
(3) Using a scooter.
(4) Flushing.

KITE KITE

A device for hydraulically cleaning sewer lines. Resembling an airport wind sock and constructed of canvas-type of material, the kite increases the velocity of a flow at its outlet to wash debris ahead of it.

MECHANICAL CLEANING MECHANICAL CLEANING

Clearing pipe by using equipment that scrapes, cuts, pulls or pushes the material out of the pipe. Mechanical cleaning devices or machines include bucket machines, power rodders and hand rods.

ORIFICE (OR-uh-fiss) ORIFICE

An opening in a plate, wall or partition. An orifice flange set in a pipe consists of a slot or hole smaller than the pipe diameter. The difference in pressure in the pipe above and at the orifice may be related to flow in the pipe.

POWER RODDER POWER RODDER

A sewer-cleaning machine fitted with auger rods which are inserted in a sewer line to dislodge and cut roots and debris.

PREVENTIVE MAINTENANCE PREVENTIVE MAINTENANCE

Regularly scheduled servicing of machinery or other equipment using appropriate tools, tests and lubricants. This type of maintenance can prolong the useful life of equipment and machinery and increase its efficiency by detecting and correcting problems before they cause a breakdown of the equipment.

ROD (SEWER) ROD

A light metal rod, three to five feet long with a coupling at each end. Rods are joined and pushed into a sewer to dislodge obstructions.

RODDING RODDING

A method of opening a plugged or blocked pipe by pushing a steel rod or snake, or pulling same, through the pipe with a tool attached to the end of the rod or snake. Rotating the rod or snake with a tool attached increases effectiveness.

RODDING MACHINE RODDING MACHINE

A machine designed to feed a rod into a pipe while rotating the rod.

RODDING TOOLS RODDING TOOLS

Special tools attached to the end of a rod or snake to accomplish various results in pipe rodding.

ROTAMETER (ROW-ta-meter) ROTAMETER

A device used to measure the flow rate of gases and liquids. The gas or liquid being measured flows vertically up a calibrated tube. Inside the tube is a small ball or a bullet-shaped float (it may rotate) that rises or falls depending on the flow rate. The flow rate may be read on a scale behind the middle of the ball or the top of the float.

SCOOTER SCOOTER

A sewer-cleaning tool whose cleaning action depends on the development of high water velocity around the outside edge of a circular shield. The metal shield is rimmed with a rubber flange and is attached to a framework on wheels (like a child's scooter). The angle of the shield is controlled by a chain-spring system which regulates the head of water behind the scooter and thus, the cleansing velocity of the water flowing around the shield.

SEWER BALL SEWER BALL

A spirally grooved inflatable semi-hard rubber ball designed for hydraulic cleaning of sewer pipes. See BALLING.

STOPPAGE

(1) Partial or complete interruption of flow as a result of some obstruction in a sewer.

(2) When a sewer system becomes plugged and the flow backs up, it is said to have a "stoppage." Also see BLOCKAGE.

(3) The place and cause of a stoppage. Example: "Fifty-one feet from a specific manhole" and "a grease stoppage."

CHAPTER 6. PIPELINE CLEANING AND MAINTENANCE METHODS

(Lesson 1 of 5 Lessons)

6.1 HOW TO IDENTIFY PROBLEMS AND SELECT SOLUTIONS

6.11 Objectives of a Sewer Cleaning and Maintenance Program

To operate and maintain a wastewater collection system so it will function as intended, try to strive towards the following objectives.

1. Minimize the number of stoppages per mile of sewer.
2. Minimize the number of odor complaints.
3. Minimize the number of lift station failures.

This chapter discusses how to identify the causes of stoppages and odors, how to select solutions to these problems, and how to actually solve these problems. Lift station problems and prevention of failures are presented in Chapter 8, Lift Stations, and Chapter 9, Equipment Maintenance.

6.12 Identification of Problem

Potential problems are often found during routine cleaning and maintenance. Our job is to try to prevent stoppages that will result in wastewater backing up and overflowing onto the street or into homes or businesses. Webster's Dictionary defines a stoppage as the act of stopping or arresting motion, progress or action; also, the state of being stopped or halted, such as an obstruction or a block in a water pipe. Therefore, we can consider a sewer stoppage to occur when a sewer system becomes plugged and the flow backs up. Sometimes a stoppage can occur, but the flow is not completely stopped. Some flow will leak or seep by the stoppage.

6.121 Types of Stoppages

For the sake of recording stoppages for follow-up maintenance work, stoppages must be identified according to the cause or type of problem. Stoppages are caused by obstructions such as roots, grease, debris, broken pipe or a joint failure. These obstructions may require removal, repair, or replacement immediately to correct the problem.

Many stoppages are caused by people not realizing the consequences of their activities. For example, vandals have placed debris into lines and structure openings which were designed to vent the collection system. Also, they have placed materials or debris into structures designed for the purpose of performing maintenance work in the sewers. Manhole covers have been removed in isolated sewer easements by vandals. These openings offer an ideal place for vandals to cause a serious back up of wastewater in a very critical area.

Some stoppage problems created in sewer easement areas also may be caused unintentionally. This is especially true when a large piece of construction equipment begins rough grading work and this equipment knocks off the top of a manhole, spilling dirt, rocks, and other material debris into the opening and causing a stoppage in the sewer. In most cases, the equipment operator is not aware of the location of the manholes because they are buried or covered with overgrowth.

Other physical type stoppages are caused by obstructions found in the *BARREL*[1] of the sewer. These obstructions are sometimes found to be created by plumbers, equipment, or by some force of nature. A plumber-made obstruction can be caused by the placement of a building sewer tap connection that protrudes into the main sewer, a poorly repaired pipe section, backfill damage to pipe and the misuse of trench compaction equipment, pipe damage due to the improper use of sewer cleaning equipment and other such physical contributions.

The forces-of-nature type of obstructions include the penetration of roots into the pipe connection or openings which cause pipe to break and/or restrict water flow. Ground movement shifting the pipe (such as caused by earthquakes), weather changes, soil conditions underground, and the deterioration of other utility pipes are effects caused by natural forces that could produce obstructions.

Some of the most common types of debris found when removing a stoppage are a build up of solidified grease, detergents, sticks, rags, plastic bags, broken pipe, brick, rocks, sand, eggshells and silt, to name a few. Larger items removed from lines and manhole openings which have caused a major problem for removal are broken manhole and flushing inlet castings; concrete and asphalt rubble; steel rebars; large metal and plastic buckets; broken and lost plumber rods, snakes and plugs; wooden posts and timber materials; barb wire; tree limbs, stumps and many other items.

---

[1] *Barrel. The cylindrical part of a pipe that has a bell on one end.*

In some instances where the invert of a small diameter sewer is connected to the invert of a large diameter sewer which is flowing at maximum flows, hydraulic conditions can cause serious stoppages to develop. Not only do stoppages develop in the sewer, but solids can build up in a manhole and produce harmful and obnoxious gases. Most instances of a hydraulic-caused-stoppage condition are found to be in sewers that have been extended to new developments from existing mains which were not designed for the future potential growth of a community.

Hydraulic-caused stoppages can be minimized by proper design. Wherever flows from one sewer meet and join the flow in another sewer, the flows should always be going downstream in the same direction as much as possible. A more frequent cleaning schedule is the best possible solution to hydraulic-caused stoppages in many cases.

6.122 Identifying Causes of Stoppages and Problems

First, try to correct the problem as quickly as possible. If the cause of the stoppage can be identified, the best method of correcting it comes next.

A mental check list to identify the problem would include:

1. Does this line have a history of previous stoppages? (A root problem line or a grease problem line.)
2. Are trees growing near the line?
3. Have new building sewers or new lateral or branch sewers been installed recently?
4. Have repairs been made recently to the sewer, to other utilities or to the street?
5. Are there any ground or surface indications, such as a settlement or a sink hole?

Once the cause of the problem has been identified, the methods for solving the problem can be analyzed.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 352.

6.1A To operate and maintain a wastewater collection system properly, what objectives should be considered?

6.1B What happens when a stoppage or blockage occurs in a sewer?

6.1C What are the major causes of stoppages?

6.1D How would you attempt to identify the cause of a stoppage?

6.13 Methods for Cleaning and Maintaining Sewers

Sewer cleaning and maintenance methods depend on the characteristics of the wastewater being conveyed to the treatment plant, fluctuations in wastewater flows, alignment or grade of the sewer, pipe material and condition of the sewer.

Stoppages can be cleared or prevented and sewers cleaned by either hydraulic or mechanical methods. Hydraulic cleaning methods consist of cleaning a sewer with water under pressure that produces high water velocities. These velocities are usually high enough to wash most grit, grease and debris found in sewers down the sewer and leave the pipe clean. Mechanical methods of clearing stoppages or sewers consist of using equipment that scrapes, cuts, pulls or pushes the material out of the pipe.

Hydraulic cleaning equipment used today includes high velocity cleaners, balls, kites, bags, parachutes, tires and scooters. High velocity cleaners rely on jets of high velocity water squirting from a nozzle at the end of a hose in a sewer. The high velocity water cleaners also are called "jet cleaner," "jet rodder," "hydraulic cleaner," or "high pressure cleaner." Balls, kites, bags, parachutes, tires and scooters all rely on the same principle. These devices fit into a sewer and partially block the flow. Water builds up behind the device and creates a pressure. This pressure forces water at a high velocity around the outside edge of the cleaning device. This high water velocity cleans the walls of the sewer and pushes the material and debris downstream where it can be removed at a manhole. Flushing is a hydraulic cleaning method that relies on additional water being discharged into a sewer in sufficient quantities to create high velocities and clean the sewer.

Mechanical cleaning equipment consists of bucket machines, power rodders, hand rods, and winches for pulling scrapers, porcupines and swabs. A bucket machine operation includes a special type of device that is pulled along a sewer. This device removes debris as it is pulled along the sewer. Rodding (by power or hand) consists of pushing or pulling a steel rod or snake through a sewer with a special tool attached to the end. Mechanical devices are more effective clearing than at cleaning and the sewers sometimes have to be flushed after being cleared.

Both hydraulic and mechanical cleaning methods are used to maintain sewers in working condition. Chemicals and bacteria cultures also are used in sewer maintenance programs to keep lines clear.

Odor control (especially hydrogen sulfide control) requires that sewers be maintained as clean as possible. Hydraulic and mechanical cleaning methods as well as chemicals are used in odor control programs to maintain wastewater collection systems.

TABLE 6.1 CLEANING AND MAINTENANCE PROBLEMS AND SOLUTIONS

Identification of Problem	Source or Cause	Solution Method	Section	Comments
1. Stoppages — Emergency a. Manhole overflowing	1.a Grease	Hand Rods Power Rodder	6.33	Rod from downstream manhole with a 4-inch auger into stoppage. When clear, then run 6-inch or larger auger through restricted area. Write work request to high velocity clean or ball line as soon as possible. If cannot open with hand rods, try high velocity cleaner.
b. Flooding of residences or businesses			6.22	Hand rods and power rodders will usually unplug most grease stoppages. A high velocity cleaner will open most grease stoppages.
	1.b Roots	Hand Rods	6.33	Rod from downstream manhole with 4-inch auger or saw. Be cautious in opening stoppages if there is a high head on the upstream manhole. Remove as much of the root mass as possible. Request TV inspection for root concentration; schedule power rodding to open line and chemically treat to control future root growth. Hand rods are effective 90% of the time. If cannot clear roots with hand rods, try high velocity cleaner.
		High Velocity Cleaner	6.22	High velocity cleaner will usually open stoppage and restore service. Schedule TV check and chemical treatment. If unable to clear roots with high velocity cleaner, try power rodder.
		Power Rodder	6.32	Power rod line to clear stoppage. Schedule TV check, cleaning, and chemical treatment.
	1.c Debris Stoppage Such as Rocks, Lumber			Caused by broken lines, open manholes, vandalism.
		High Velocity Cleaner	6.22	Clean line with high velocity cleaner.
		Power Rodder	6.32	Use caution. May jam tool in line requiring a dig up to clear line and remove broken rod and tool.
2. Grease a. Stoppage Causes Grease Build Up	a. Restaurant on Blocked Segment of Sewer	a. High Velocity Cleaner	6.22	High velocity cleaner is an effective tool in removing grease build ups in line sizes up to 15 inches. High velocity cleaner becomes ineffective in larger diameter pipes.
b. TV Report on Routine Inspection	b. Low Velocity Allowing Grease Build up From Home Disposal Unit Problems Often Develop where High Velocities are Suddenly, Slowed Down	b. Balling (or tire)	6.21	Balling will remove grease deposits from pipe walls, but will not clean as effectively as properly used high velocity cleaner.
c. Observe Build up on Side Walls of Sewer		c. Scooter (or kite)	6.24	More effective in lines above 18-inch diameter than high velocity cleaner.
		d. Power Rodder	6.32	Extensively used, but not as effective in grease removal as high velocity cleaner and balling — usually ineffective in lines above 10-inch diameter.
d. Past records		e. Chemicals	6.54	Be sure to insist on a performance contract. Do not pay until the chemical or material performs as claimed.
		f. Bacteria Cultures	6.54	Specific cultures are required for collection system maintenance.
e. Grease Trap		a. Clean Trap Regularly	6.54	A regular maintenance program must be established and continued.
		b. Bacteria Cultures	6.54	Specific cultures are required for collection system maintenance.
3. Roots a. TV Report	a. Trees and Shrubs	a. Chemicals	6.5	For long-term control, chemical treatment provides the best solution with up to three years between application rates.
b. Poor Joints or Damaged Pipe Allow Root Entry		b. Power Rodder	6.32	May be used to clean an opening so that flow may pass. Cutting roots is like pruning shrubs, it stimulates root growth. If power rodding is only control used, must frequently redo that segment of line.
		c. High Velocity Cleaner	6.22	Special root cutters are available.

TABLE 6.1 CLEANING AND MAINTENANCE PROBLEMS AND SOLUTIONS (CONT.)

Identification of Problem	Source or Cause	Solution Method	Section	Comments
c. Past Records	d. Repairs		Chap. 7	If TV report shows only one section of broken line or a few bad joints, dig up and repair. If a great number of defects are observed, consider pressure sealing or relining the pipe by insertion of a liner.
4. Sand, Grit, Debris a. TV Report	a. Eggshells, coffee grounds, bones from residential disposal units	a. High Velocity Cleaner	6.22	For light concentrations of grit in small lines, not effective in lines above 15-inch diameter.
b. Grit Settles During Low Flows		b. Balling (or tire)	6.21	The work horse for cleaning. Large volumes can be removed at a reasonable cost. Requires careful control in shallow lines.
c. Grit Sticks to Grease or Slimes	b. Broken china, bones, and glass from restaurant disposal units	c. Scooters and Kites	6.24	More effective in larger lines. Removes some dangers of flooding in shallow lines that balling may create if not properly controlled.
d. Routine Inspection	c. Sand, silt from poor joints and broken lines	d. Bucket Machines	6.31	Used where extreme concentrations of grit and sand have loaded the line to extent that above methods are ineffective due to cost and handling of material to be removed.
e. Past Records	d. Lines with low flows or velocities permitting deposition of solids			
5. H_2S and Odor Control	a. Force Mains	a. High Velocity Cleaner	6.22	Fast cleaning of slimes in lines up to 15-inch diameter.
a. Odor Complaints	b. Low flows and velocity	b. Balling	6.21	Best for sewers with bellies and offset joints, but expensive operation for odor control only.
b. Manhole Inspection reveals line deterioration	c. Offset Joints	c. Scooter	6.24	Fast for larger lines.
	d. Bellies in Line	d. Flushing	6.23	Small lines. Usually not effective for more than one week.
	e. Drop Manholes	e. Plug Lifting and Vent Holes in Manhole Cover		Roofing cement makes a satisfactory hole sealer.
	f. Manhole where trucks dump septic tank contents	f. Control Program	6.6	Develop program using combination of solutions.
6. System Inspection	Detects problem areas and permits realistic scheduling of preventive maintenance program	a. Closed Circuit TV	5.4	Permits thorough inspection of system. Pin-points damaged areas such as broken pipe segments, offset joints, lines not to grade, collapsed pipes, protruding service taps, root intrusion, deterioration of lines, and grease deposits. Informs you of required cleaning and the effectiveness of the cleaning method. If a stoppage reoccurs or you are curious regarding cause of problem, TV the line. The most useful tool in collection system maintenance.
		b. Air and Water Testing	3.7	Detection of sources of infiltration and exfiltration.
		c. Smoke Testing	5.5	Locates leaks when groundwater table is below sewer. Also used to determine if buildings and residences are properly connected to collection system and to identify illegal connections.
		d. Dye Testing	5.6	Identification of illegal connections and location of overflowing or leaking manholes and sewers.
		e. Pipeline Lamping	5.7	Inspection of sewers for condition, including alignment and obstructions.
		f. Visual	5.3	Lift manhole covers and observe conditions.

6.14 Selection of Solution to Problem

Some methods for cleaning sewers can be used for removing stoppages where others cannot. For specific jobs or routine preventive maintenance, different methods are available depending on whether the problem is caused by roots, grease, sand, or some other source.

Table 6.1 outlines:

1. How to identify problems and their source,
2. Methods of correcting these problems.
3. Section in manual where solution procedures are described in detail, and
4. Comments helpful for selecting the best method.

When you have a stoppage or flow problem in a sewer, try to identify the problem. Refer to Table 6.1 to see if the problem is listed. Review the methods of correcting the problem in the table, select a method, correct the problem, and evaluate the effectiveness of the solution.

This table cannot cover all problems or all equipment, but can be useful as a guide to effective and efficient collection system maintenance. The section after Table 6.1 outlines the equipment required for removing stoppages and cleaning lines, while the other sections in this chapter describe solution procedures in detail.

6.15 Equipment Required for Removing Stoppages and Cleaning Sewers

What type of equipment is best suited for removing stoppages and cleaning sewers? The answer to this question can only be determined after an analysis of the cause of the problems and the solution selected. Following is a list of the basic types of equipment used to identify and remove stoppages and clean sewers.

6.151 Rodding

Equipment: Power rodder machine (may be truck or trailer mounted) or hand rods.

Advantages: May be used to cut roots, scrape, and dislodge and remove certain types of material found in sewers. This equipment is very effective in removing collection line emergency stoppages.

Limitations: Ineffective for removing sand and grit accumulations in sewers, but may loosen material so it can be flushed out of sewer. Rods have a tendency to coil and bend when used in large diameter sewers. When using hand rods in a sewer with a high head behind an obstruction, caution must be exercised when the obstruction is broken because the rods may shoot back out of the manhole.

6.152 Sewer Ball or Tire

Equipment: Assortment of various sizes of sewer balls or tires to fit different diameters of sewers, tag line winch, cable, reels, water tank truck and dump pickup. Provide water from a hydrant through a hose with an air gap.

Advantages: Hydraulic action of spinning ball and high velocity of water flowing around ball dislodges debris from pipe walls and moves debris downstream. Very effective in removing heavy concentrations of sand, grit, rock and grease from sewers.

Limitations: Dangerous to use in locations with basement fixtures and steep-grade hill areas. Prevalent possibility of flooding dwellings. Cannot be used effectively when sewers have bad offset joints or protruding service connections because ball can become distorted, get past these obstructions and not do an effective cleaning job. In sewers where the ball has a tendency to get stuck, a bag full of ice can be used. When the bag becomes stuck, wait for the ice to melt sufficiently for the bag to continue downstream.

6.153 High Velocity Cleaner

Equipment: Truck mounted high velocity water machine, manhole hose guide, debris traps, and dump pickup or debris trailer.

Advantages: Very effective in cleaning flat, slow flowing sewers. Efficient in removing grease, sand, gravel, and debris in smaller diameter sewers. Effective in breaking up solids in manholes and washing structures. May be used to remove emergency stoppages.

Limitations: Efficiency and effectiveness in removing debris from larger diameter lines decrease as the cross-sectional area of the pipe is increased. This method, when used by an inexperienced operator, may cause a back up into residences. Extra time by an experienced operator may be necessary to remove grease and roots from some locations.

6.154 Bucket Machine

Equipment: Power bucket machine, power bucket truck loader, dump truck, and manhole jacks.

Advantages: Removes large amounts of sand and debris from larger diameter sewers, but may leave as much as it removes. A sewer should be cleaned by other methods after being cleared with a bucket machine.

Limitations: Can damage sewers. Setting up equipment is time consuming.

6.155 Kite or Bag

Equipment: Water tank truck, dump pickup truck, and power drum winch machine.

Advantages: Very effective in moving accumulations of decayed debris and grease downstream. Capable of washing ahead of it a full pipe of deposits, including roots.

Limitations: Must use caution in locations with basement fixtures and steep-grade hill areas.

6.156 *Scooter*

Equipment:	Water tank truck, dump pickup truck, tag line, and power winch. Provide water from a hydrant through hose with an air gap.
Advantages:	Hydraulic water action scours inside of line. Very effective in removing heavy debris and cleaning grease from line.
Limitations:	When cleaning larger lines, the manholes must be designed to a larger size to receive and retrieve this equipment or the scooter must be assembled in the manhole. Must use caution in locations with basement fixtures and steep-grade hill areas.

6.157 *Flushing*

Equipment:	Water tank truck and fire hose if fire hydrant is not convenient.
Advantages:	Supplies a surge of water to move light, decaying organic matter downstream in slowly flowing sewers.
Limitations:	Causes a temporary movement of debris from one point to another in the collection system. Flushing does not remedy the cause of the problem and does not move heavy debris and grit. Must use caution in locations with basement fixtures and steep-grade hill areas.

6.158 *Scraper*

Equipment:	Wing scraper, "C" drag bucket, power bucket machine, basin machine and dump truck or bin.
Advantages:	Removes large amounts of sand, stone, rocks and debris from larger (usually 36-inch diameter or larger) sewers.
Limitations:	Sewers can be damaged. Setting up of equipment is time consuming; therefore, the operation is usually run in two or three shifts during a 24-hour period.

6.16 Summary of Solutions

Table 6.2 shows the relative effectiveness of the possible solutions to different problems. The larger the size of the box in the square, the more effective the solution is for a particular problem. One problem may have several effective solutions and another problem may have only one possible solution. *REMEMBER* that Table 6.2 is a summary table to provide you with an indication of the general effectiveness of solutions. *YOU* must evaluate every problem and select the best solution using available equipment.

TABLE 6.2 EFFECTIVENESS OF SOLUTIONS

		TYPE OF PROBLEM			
SOLUTION TO PROBLEM	Emergency Stoppages	Grease	Roots	Sand, Grit, Debris	Odors
Balling[1]		☒		☒	☒
High Velocity Cleaning	☒	☒		☒	☒
Flushing					☒
Sewer Scooters		☒		☒	
Bucket Machines, Scrapers				☒	
Power Rodders	☒	☒	☒		
Hand Rods	☒[3]	☒	☒		
Chemicals[2]		☒	☒		☒
Bacteria[4]		☒			

---

[1] *Kites, tires, bags, parachutes, scooters, and cones are commonly used instead of balls in large sewers (greater than 24 inches in diameter) with similar results.*

[2] *Effectiveness depends on type of chemical and its intended use.*

[3] *Power rodders and high velocity cleaners may be faster (if available) under certain conditions.*

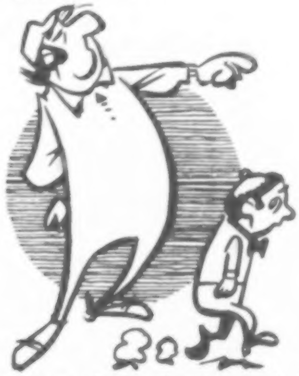
[4] *Effectiveness depends on formulation of cultures.*

6.17 Work Assignment

When a crew is assigned a regularly scheduled sewer cleaning job, the crew should be notified and dispatched by a written order (see Chapter 7, Section 7.15, Work Request Form). Crews assigned to clear emergency stoppages are notified by radio and immediately attempt to clear the stoppage. A written report is prepared after the stoppage is cleared. Work performed also must be recorded. This information provides vital documentation of the ability of the wastewater collection system to perform its intended job and also the effectiveness of equipment and crews. Chapter 12, Section 12.2, Records, provides a discussion of the need for records and the value of records.

The crew chief for most cleaning operations is the Maintenance Equipment Operator.[2] The chief receives the work assignments for the day from a Maintenance Supervisor I (depends on size of agency who prepares and makes work assignments). Work assignments should include the following information for each location:

1. Location of job, including map book number, map page and manhole number.
2. Street or easement.
3. Location of upstream and downstream manholes.
4. Line-of-sight or sound-powered telephone communications.
5. If in street, traffic conditions, or
6. If in easement,
   a. Notification of property owners.
   b. Are dogs locked up?
   c. Keep children out of work area.
7. Sewer conditions.
   a. Size.
   b. Depth.
   c. Water supply needed.



Upon arrival at the work site, the sewers to be cleaned are located using a map.

6.18 Records

A record of all cleaning operations should be made (Figure 6.1) and filed for future reference. These records should include the date, street name or number, line size, distance, and manhole numbers or identification. Also note the kind and amount of materials removed, wastewater flow, and amount of auxiliary water used. If particular problems were encountered, these too should be noted, especially exact location of obstructions. See Chapter 11, Section 11.2, Records, for details on how to prepare record forms, complete forms (Figure 6.1), analyze records, and file records.

If pieces of broken sewer are removed, this may indicate a TV inspection is needed and a repair made on the broken sections of pipe.

Recording traffic patterns at a site can be very helpful next time equipment must be set up at the location. Indicate where cars park (such as over manholes), traffic volume during rush hours, and whether police traffic control should be called for help before going to the site.

Computers are being used in many aspects of collection system operation, maintenance and recordkeeping. Computer software packages are available for scheduling preventive maintenance activities, issuing work orders for repairs, keeping track of where work is done, who did the work, when, and the labor and materials required. With the proper software any information in the computer's records can be recalled for future use. Computers are also used to keep spare parts inventories and to order spare parts when the supply runs low and before they are needed for scheduled maintenance and repairs.

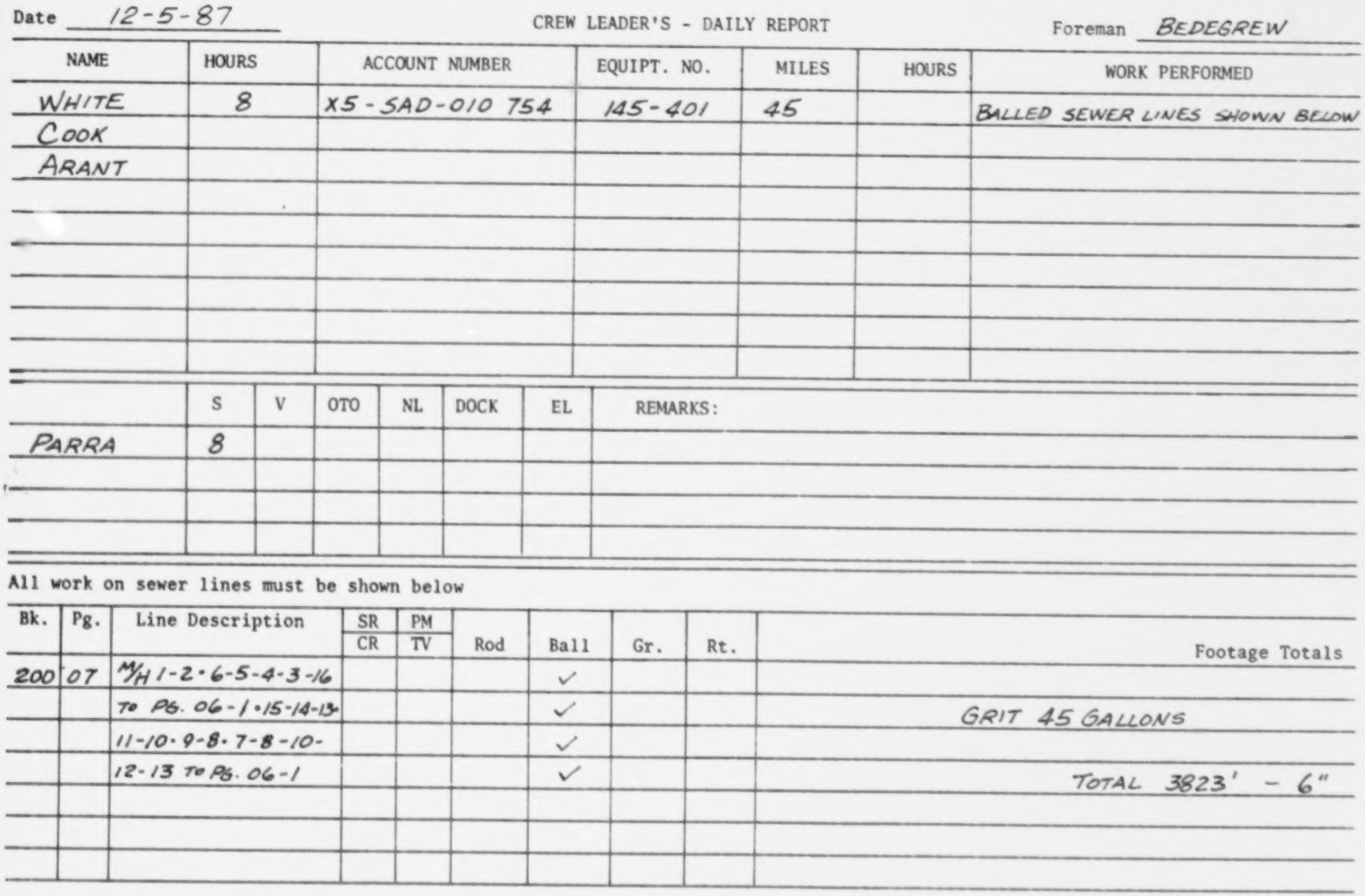
When making out records, remember that you or someone else will be referring to them. The more complete the record, the easier the next operation becomes since you have a history of this sewer.

6.19 Notify Wastewater Treatment Plant

After clearing a large septic stoppage, be sure to notify the operator on duty at the downstream wastewater treatment plant. Septic stoppages develop when the sewer has been blocked for considerable time and/or the air temperature is hot. Under these conditions the wastewater and organic solids turn black and smell like rotten eggs. If a large diameter sewer is blocked and a considerable volume of wastewater backs up in the pipes, there might not be sufficient fresh water arriving at the treatment plant to dilute the septic wastewater. When a large volume of septic wastewater reaches a treatment plant, the treatment processes can become upset and fail to do their intended job. By notifying the operator in advance of the location of the stoppage and approximate volume of septic wastewater flowing towards the treatment plant, the operator can be alerted and get prepared to minimize the impact on the treatment processes.

---

[2] *Portions of this section and job titles are from "Manpower Requirements for Wastewater Collection Systems," by Elie Namour for EPA, Grant No. 900211, March, 1974.*



Date 12-5-87

CREW LEADER'S - DAILY REPORT

Foreman BEDEGREW

NAME	HOURS	ACCOUNT NUMBER	EQUIPT. NO.	MILES	HOURS	WORK PERFORMED
WHITE	8	X5-SAD-010 754	145-401	45		BALLED SEWER LINES SHOWN BELOW
COOK						
ARANT						

	S	V	OTO	NL	DOCK	EL	REMARKS:
PARRA	8						

All work on sewer lines must be shown below

Bk.	Pg.	Line Description	SR	PM	Rod	Ball	Gr.	Rt.	
			CR	TV					Footage Totals
200	07	M/H 1-2·6-5-4-3-16				✓			
		TO PG. 06-1·15-14-13-				✓			GRIT 45 GALLONS
		11-10·9-8·7-8-10-				✓			
		12-13 TO PG. 06-1				✓			TOTAL 3823' - 6"

Fig. 6.1 Daily maintenance report

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 352.

6.1E When a grease or root stoppage causes flooding, what is the first method attempted to solve the problem?

6.1F What is the most effective method of removing grease build ups?

6.1G How can a stoppage caused by roots be cleared?

6.1H List the advantages and limitations of a high velocity cleaner.

END OF LESSON 1 OF 5 LESSONS
ON
PIPELINE CLEANING AND MAINTENANCE METHODS

DISCUSSION AND REVIEW QUESTIONS

Chapter 6. PIPELINE CLEANING AND MAINTENANCE METHODS

(Lesson 1 of 5 Lessons)

At the end of each lesson in this chapter you will find some discussion and review questions that you should answer before continuing. The purpose of these questions is to indicate to you how well you understand the material in the lesson. Write the answers to these questions in your notebook before continuing.

1. Why should the cause of a stoppage be identified?
2. What are the causes of stoppages?
3. How would you select a method to clear a stoppage?
4. What are the advantages and limitations of sewer balls in comparison with other methods of cleaning sewers?
5. How would you determine if a sewer needed cleaning?
6. What would you do if you encountered an emergency stoppage with wastewater flowing out a manhole and down the street?

CHAPTER 6. PIPELINE CLEANING AND MAINTENANCE METHODS

(Lesson 2 of 5 Lessons)

6.2 HYDRAULIC CLEANING

Sewer cleaning methods described in this section rely on the cleansing action caused by high velocities of water in the line. High water velocities can effectively remove grease, sand, and other debris. Cleansing velocities can be obtained by allowing water pressures or head to build up in the line or by using a pump to produce the water pressure. Hydraulic cleaning methods include balling, high velocity cleaners, flushing, sewer scooters, kites, tires and poly pigs.

WARNING

WHEN USING THESE METHODS, CAUTION **MUST** BE TAKEN TO BE SURE BASEMENTS AND HOMES ARE **NOT** FLOODED

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 352.

6.2A List three sewer line hydraulic cleaning methods.

6.2B What is a major precaution that must be exericsed when hydraulic cleaning methods are being used?

6.21 Balling

Balling is one method of removing debris from sewers. The tool is literally a "ball" of special design (Figure 6.2).

This cleaning procedure is one of the less expensive methods and is quite popular in some cities. Usually balling is not the only cleaning method used by a sanitation agency since the ball primarily removes deposits of inorganic (grit) material lying on the bottom of the line and grease build-up inside the line. Balling can be used only in areas where the necessary water pressure behind and around the ball can be obtained without flooding basements or homes at low elevations. Flooding can occur when the elevation of the head of water on the upstream side of the ball is higher than a plumbing fixture in a home or basement. If many roots are involved, a power rodding machine probably will be needed. Power rodding and other cleaning methods and procedures will be discussed fully in other sections of this chapter.

Balls are available in sizes 6, 8, 10, and 12 inches for small lines and sizes up to 48 inches for large trunk lines. Larger sizes may be obtained by special ordering.

Balling is most commonly used in preventive maintenance programs. Under these conditions balling is very effective in reducing the possibility of stoppages developing. An effective balling program can reduce the production of hydrogen sulfide (see Section 6.6, Hydrogen Sulfide Control) in collection systems, thus reducing damage from hydrogen sulfide caused corrosion and the release of odors smelling like rotten eggs.

Some sewers require cleaning by balling more frequently than others. Required frequency of cleaning may vary from six months in some sluggish lines, to three years in other lines. Realize that these are typical frequencies and that some sewers may require monthly cleaning while other sewers may never need cleaning. Many communities try to ball their entire collection system every year. To determine the frequency of balling for your collection system, study your agency's records. Base the frequency of cleaning the various sections of the collection system upon:

a. Reducing the number and types of stoppages and complaints by analyzing records and inspecting manholes for the presence and amount of deposits.

b. Size of area the collection system serves.

c. Types of waste carried by collection system:

    1. Residential
    2. Commerical
    3. Industrial
    4. Storm water

The main purposes of balling or use of tires are to keep the sewer clear of debris and to maintain flow velocities of two feet per second or more in the sewers to the wastewater treatment plant.

6.211 Manpower and Equipment

At least three operators are needed for cleaning lines up to 18 inches. When cleaning those lines located in easements or off the street, additional help may be required depending on the difficulty of the job. Manpower requirements[3] are as follows:

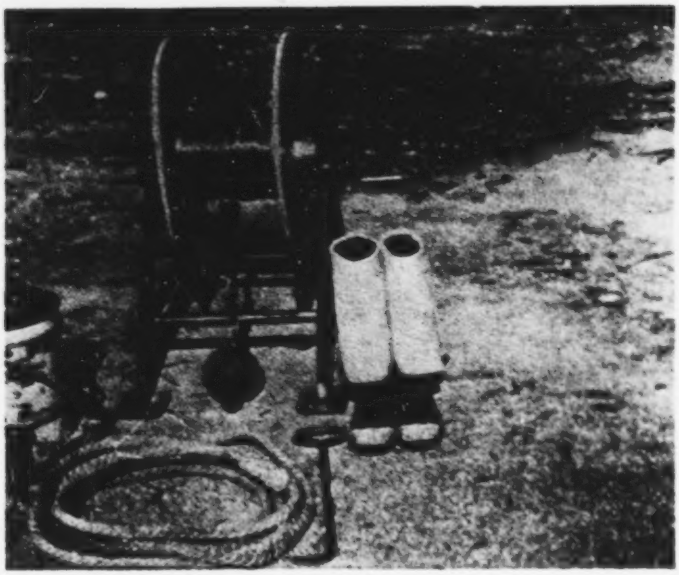
1. Maintenance Equipment Operator,
2. Maintenance Man 1, and
3. Maintenance Man 1.

Although some of the equipment listed below is used for balling, the majority of collection system maintenance departments will have most of the regular tools needed. Basic essentials include:

1. Water truck holding 1,000 or 2,000 gallons with hoses and air gap for hydrant use,
2. Tag line and a suitable reel to store it on (Figure 6.2) or power winch and cable (Figure 6.3),
3. Manhole jack or roller,
4. Plugs,
5. Balls (Figures 6.2 and 6.3),
6. Equipment truck,
7. Debris and grit trailer,

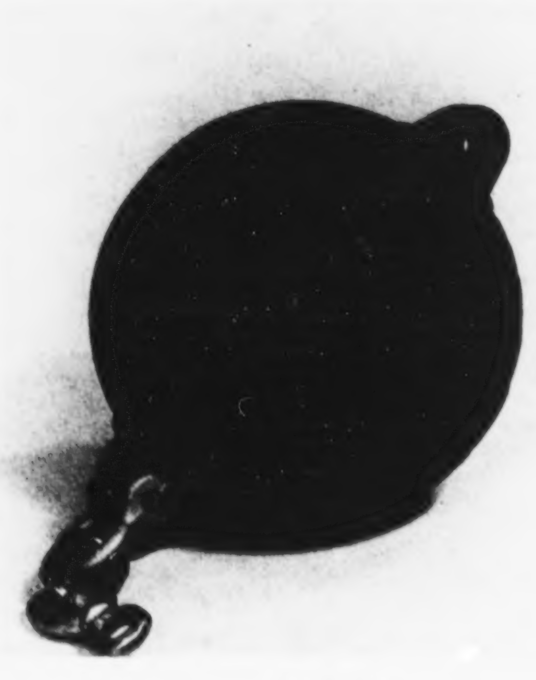
---

[3] *Job titles in this manual are from "Manpower Requirements for Wastewater Collection Systems," by Elie Namour for EPA, Grant Award No. 900212. See Special Notice on page VI at the beginning of this manual for additional information regarding job titles.*



Balling Equipment

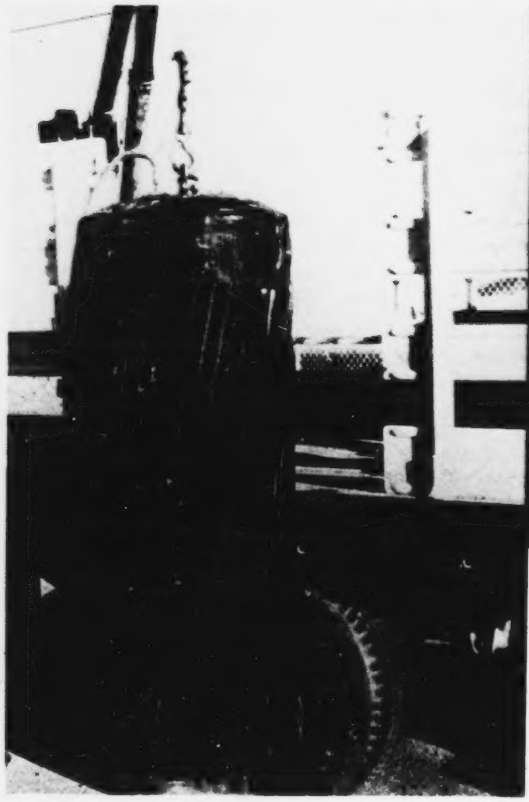
(Courtesy of Sacramento County, Water Quality Division)



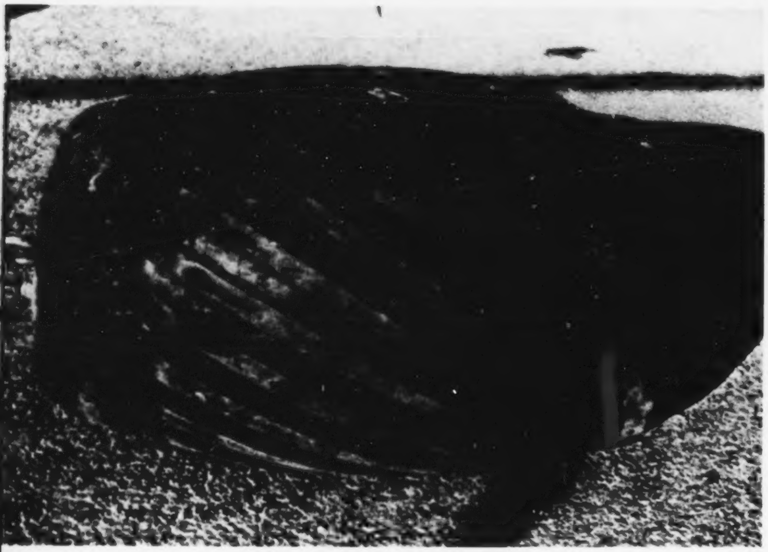
Sewer Ball

(Courtesy of the SIDU Company)

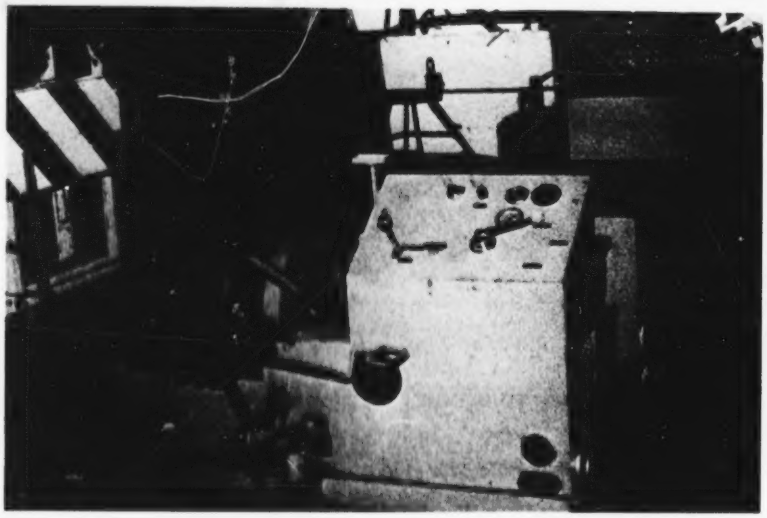
Fig. 6.2 Sewer ball and balling equipment



Multi-sized "ball," will fit through 24-inch manhole frame. Inflate and deflate to fit size of line. Will clean larger lines up to 48 inches.



Multi-sized cleaning "ball" for lines 15 through 24 inches.



Hydraulic "balling" powered winch on truck. Used for balls and tires. Winch drum holds 2000 feet of cable.

Fig. 6.3 Sewer balls and truck with power winch

(Courtesy of Union Sanitary District)

8. Ladder,
9. Manhole bars or lifters (Figure 6.4) — (Manhole hooks (Figure 6.2) can cause back injuries if not used properly).
10. Buckets, rope and manhole shovel,
11. Hip boots and gloves (Figure 6.2),
12. Sound powered telephones,
13. Collection system map,
14. Waterless hand cleaner and hand towels, and
15. Safety equipment. (See Chapter 4, Section 4.3, "Routing Traffic" and Section 4.4, "Manhole Hazards.")

Some communities use domestic water from fire hydrants instead of a water truck to obtain water to provide the necessary head for a balling operation. If fire hydrants are used, the following additional equipment will be needed.

1. Five to eight 50-foot lengths of 2.5-inch fire hose.
2. Hydrant wrench.
3. Water meter.
4. Control valve for regulating flow at manhole.
5. Traffic ramp to protect hose (Figure 6.5).
6. Hydrant gate valve.[4]
7. Air gap device (Figure 6.6).

Air gap devices are required to prevent any backflow of wastewater from a manhole into a drinking water supply. The purpose of an air gap device is to provide adequate space above the top of a manhole and the end of the hose from the fire hydrant. This gap insures that no wastewater will flow out the top of a manhole, reach the end of the hose from a fire hydrant, and be sucked back up the hose to the water supply. Suction conditions could develop if the water supply pipe near the fire hydrant should rupture and cause a washout or if any other rare condition should develop that could cause a backflow in the hose.

The tag line material may vary from plain manila rope to synthetic rope, steel cable, or plastic impregnated steel cable. Some synthetic ropes may be adversely affected by constituents in wastewater and break in many locations with no previous evidence of deterioration. Cables are considered more reliable.

The reel on which you store this tag line should hold at least 1,000 feet. The reason will be pointed out later. The reel should be portable and the rope easily uncoiled and recoiled. Power winches may hold up to 2000 feet of cable.

When cleaning lines 14 inches or larger, a power driven reel is needed and steel cable is used for the tag line. One-quarter inch diameter cable has been used with power reels for cleaning 6 inch through 18 inch diameter sewer lines. Half inch diameter cable is used for larger lines. Power bucket machines (Section 6.31, "Bucket Machines") can easily serve this dual purpose.

Power driven reels are either truck mounted or trailer mounted with stabilizer legs to hold the machines firmly in place over the manhole while in operation. Because of the terrific strain and pressure generated as water builds up behind the ball, a strong steel cable is needed. Truck mounted winches are preferred by some agencies because this method allows the truck to tow other trailer mounted equipment, such as exhaust blowers.

The smaller balls are designed with diagonal ridges and grooves on the outer surface. As water builds up in the sewer in back of the ball, water will flow through these grooves and the ball will rotate.

The outside design of the large balls differs somewhat, usually having a heavy tread surface to encourage a scouring action to the interior of the sewer (Figure 6.7).

The ball is resistant to punctures and is inflatable by means of a valve core. Into each side of the ball a strong metal eye lug is molded to which a clevis and swivel (Figure 6.8) can be attached. The tag line is then attached to control the ball and allow it to spin. This clevis and ball bearing swivel are very essential items since they keep the line from twisting. The clevis is quickly and easily fastened to the tag line and ball.

The reel, although primarily to hold the rope, also is used to apply a brake or drag to control the travel of the ball down the sewer.

The manhole guide jack or roller is essential to guide the tag line into the sewer without causing unnecessary wear and to give proper rolling action as the tag line is pulled back and forth or in restraining the ball.

Plugs, either mechanical or inflatable, are needed to control water coming into the working manhole from upstream. If there is insufficient flow in a sewer for balling, this method of "plugging off" the upstream water provides a method of getting an adequate supply of water to begin the balling procedure. Use a two-foot head of water on the ball to clean a line. Plugs are not needed if the flow in the sewer is sufficient to develop the necessary head behind a ball.

If the material removed from the line is to be hauled away by the balling crew, a truck is needed. This truck can easily be the same vehicle used to carry the balling equipment to and from the job site.

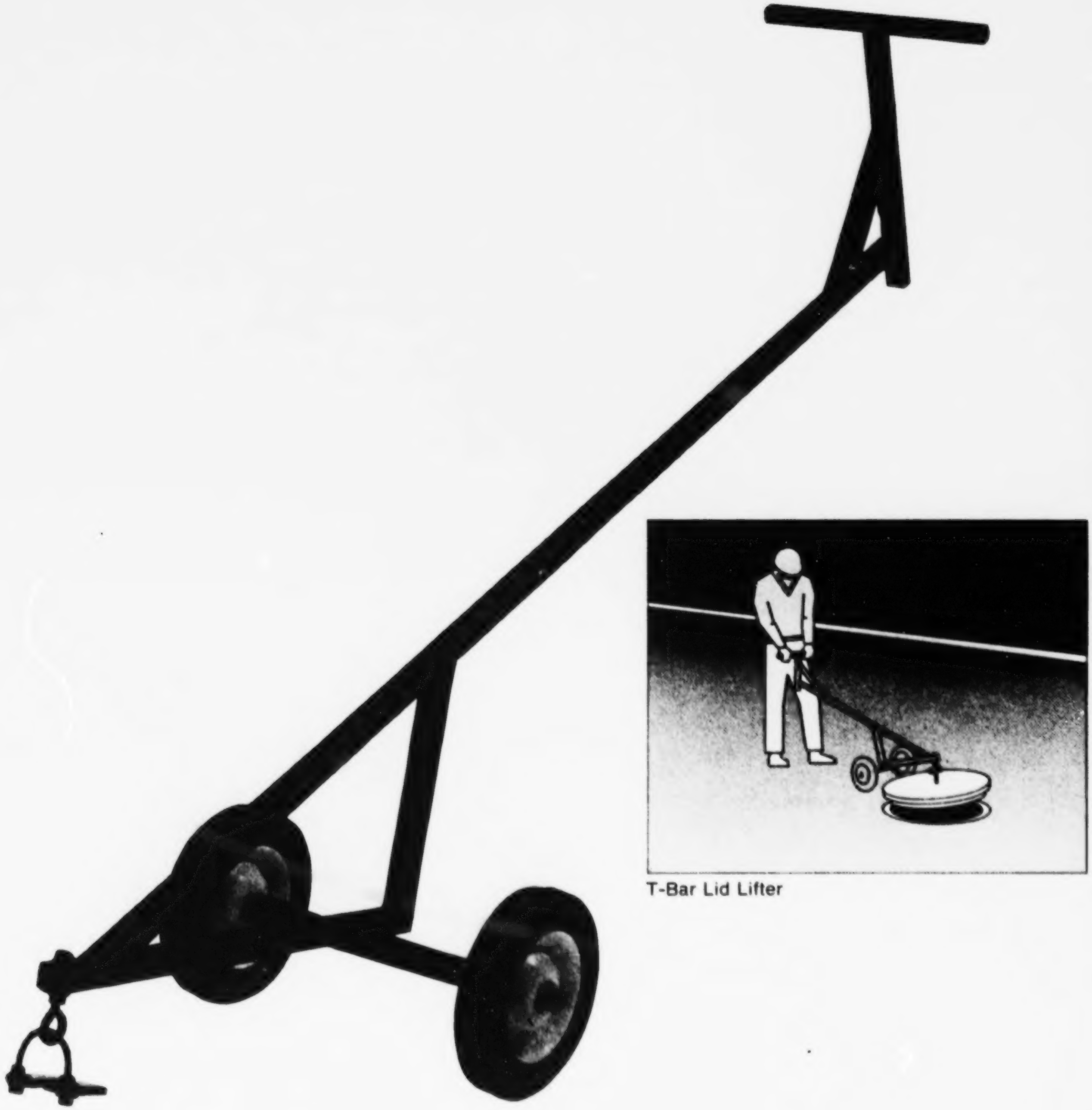
QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 352.

6.21A What kinds of deposits in sewers can be removed by balling?

---

[4] *WARNING. Use a hydrant gate valve to throttle flows from a fire hydrant. Never attempt to regulate flows from a fire hydrant using the hydrant's valve because water may flow out through the weep hole and undermine the hydrant.*



T-Bar Lid Lifter

Fig. 6.4 Manhole lid lifter
(Permission of Cherne Industries, Inc.)

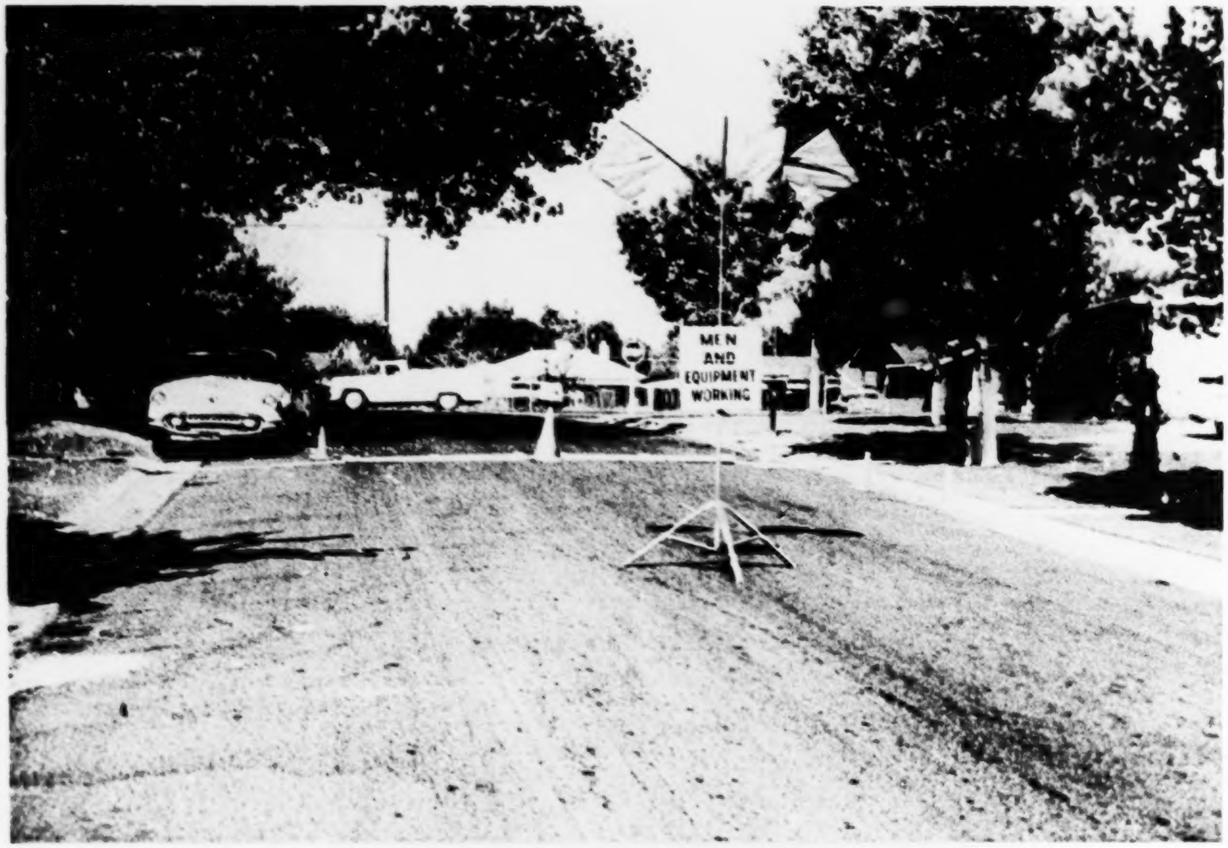

MEN
AND
EQUIPMENT
WORKING

Fig. 6.5 Traffic ramp protecting hose from traffic
(Courtesy of Sacramento County, Water Quality Division)

Fig. 6.6 Air gap devices
(Courtesy of Union Sanitary District)

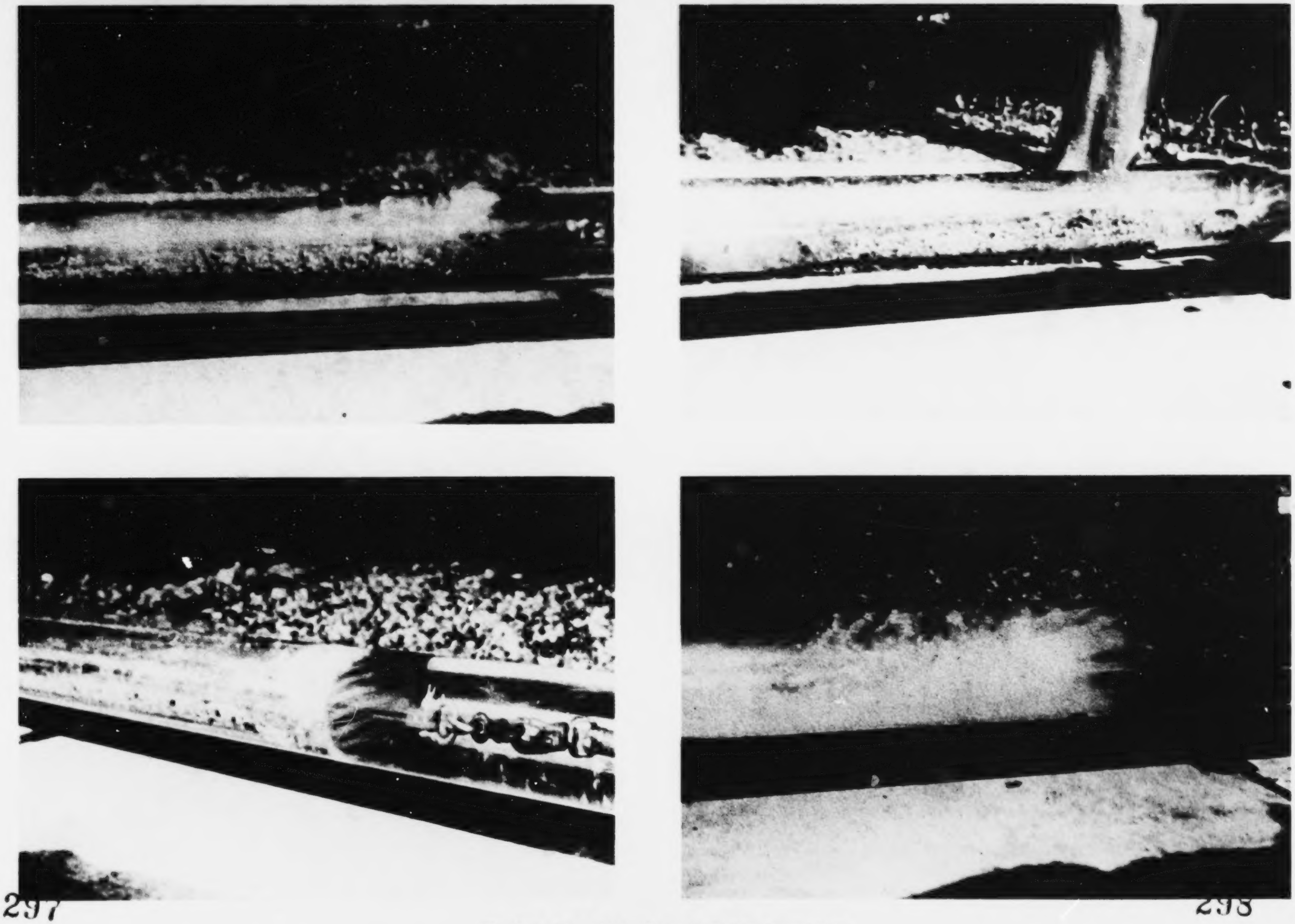


Fig. 6.7 Scouring action created by sewer ball

(Courtesy of Sacramento County, Water Quality Division)

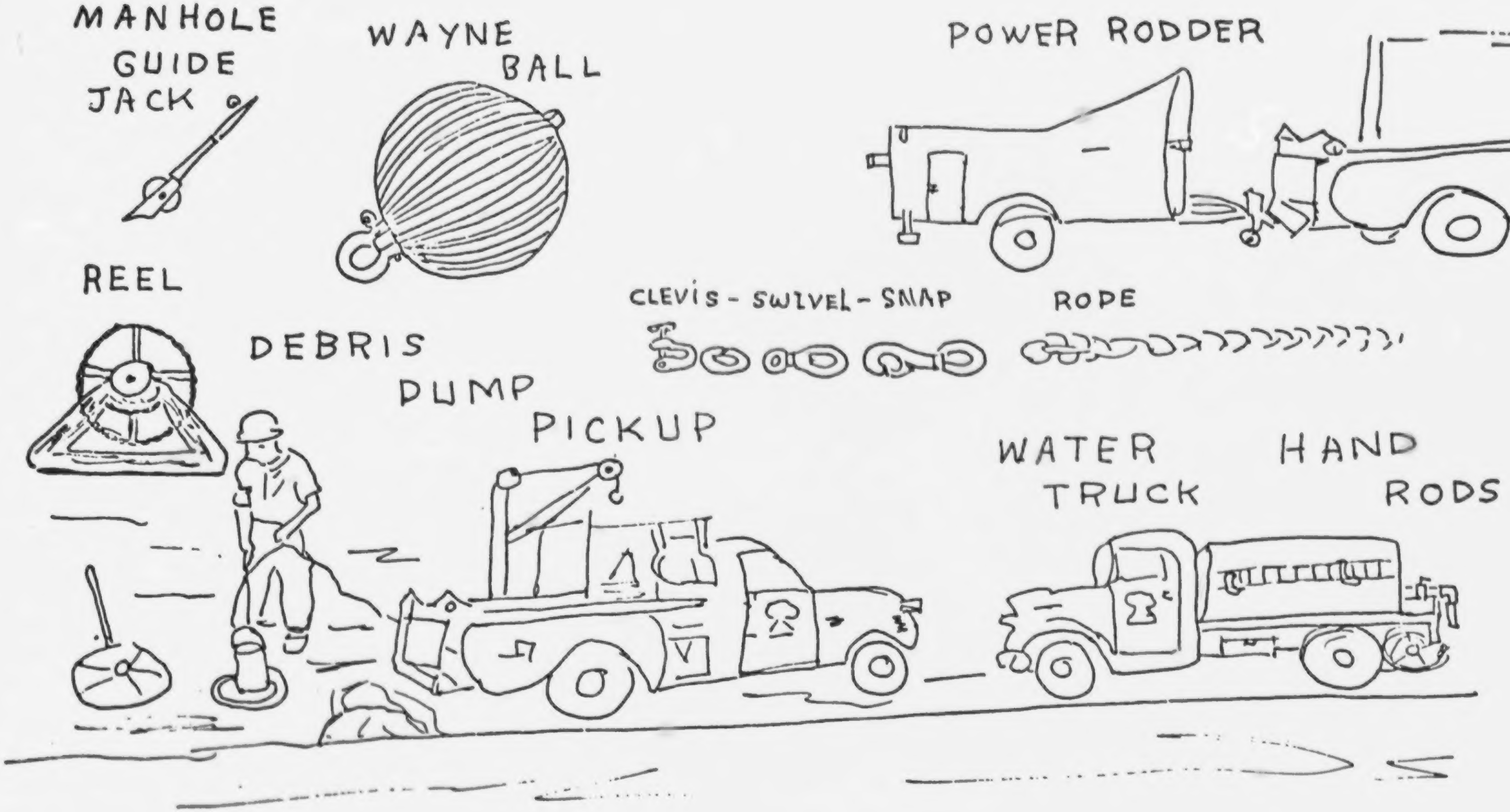

MANHOLE GUIDE JACK
WAYNE BALL
POWER RODDER
REEL
CLEVIS - SWIVEL - SNAP
ROPE
DEBRIS
DUMP
PICKUP
WATER TRUCK
HAND RODS

Fig 6.8 Balling equipment

6.21B Why is balling commonly used in preventive maintenance programs?

6.21C How frequently should a sewer be balled in a preventive maintenance program?

6.21D What is the minimum number of operators needed in a balling crew for cleaning lines up to 10 or 12 inches?

6.21E Where is the additional water obtained to provide the necessary head for a balling operation when flows in the sewer are low?

6.21F What is the purpose of the manhole guide jack or roller?

6.21G What is the purpose of an "air gap?"

6.212 Equipment Set Up

Procedures for equipment set up before cleaning sewers with a ball are outlined and discussed in the next two sections. Each operator on the crew must do the specified duties for the crew to be as efficient and productive as possible.

Before setting up the balling operation, certain safety measures need to be taken, both for handling street traffic and personal safety at and in the manholes (see Section 4.3, Routing Traffic and 4.4, Manhole Hazards). Now is a good time for a tailgate safety session (Section 11.2).

TRAFFIC ROUTING
HI! PLEASE TURN BACK AND REVIEW SECTION 4.3 ON PAGE 116

MANHOLE HAZARDS
HI! PLEASE TURN BACK AND REVIEW SECTION 4.4 ON PAGE 124

Position the reel or power equipment so the tag line is centered in the upstream or working manhole (Figure 6.8 and 6.9). Attach the line to the ball using the clevis and swivel. Place the ball in the manhole by hand, unless the water is too high. If the water is high, push the ball into place with a forked rod. Insert the ball into the sewer just far enough to determine if it is inflated properly. The ball needs to be snug enough to cause good cleaning action (Figure 6.7), but not so tight the water cannot flow around the ball and carry it downstream. On the other hand, if it is too loose the ball will only float downstream with little cleaning action. When inflating the ball, be careful that it does not become too hard. The ball must be soft enough so it can squeeze around obstructions in the sewer.

Most sewer balls have two nipples on opposite sides that are used to attach the line to the ball. If one nipple breaks, use the other nipple. *DO NOT ATTACH A LINE TO ONE NIPPLE FROM THE UPSTREAM MANHOLE AND A LINE TO THE OTHER NIPPLE FROM THE DOWNSTREAM MANHOLE, BECAUSE THIS WILL CAUSE A REDUCTION IN THE SWIRLING ACTION OF THE BALL AND THUS REDUCE THE CLEANING ACTION.*

The manhole guide jack or roller is now installed in the bottom of the manhole and secured to allow the tag line to run freely and away from areas of the manhole that will cause abrasion. This roller or jack must be secure enough to allow strain on the tag line without lifting the jack out of position.

An operator is stationed at the downstream manhole with adequate communication with the operator running the ball and tag line at the upper manhole. The downstream operator's job is to keep the operator guiding the ball informed of conditions in the downstream manhole during the balling operation.

6.213 Cleaning Operation

The balling operation is now ready to begin. If the water supply coming into the working manhole is not enough to give proper head pressure, the plugs can be used. Insert plugs into lines coming into the manhole so the section of pipe being cleaned is isolated. Discharge water into upstream manhole with the water truck or from a fire hydrant with an air gap over the manhole (Figure 6.6). Usually a balling operation will function very well with 2.0 feet of head in the upstream manhole to create a scouring velocity around the ball. There should be a maximum elevation set by the crew leader that the water head may reach. If plugs are used to store water in the upstream line for release to operate the ball, be sure to attach a safety line securely to them. When the plug is released, the water pressure behind it will have a tendency to "blow" it out and there is the danger of losing it into the downstream line and causing a major problem. Either method will create enough pressure to operate the ball properly.

As the ball begins to travel downstream, it will also be turning with water traveling around it and flushing debris ahead of it. *HOLD THE TAG LINE TIGHT AND ALLOW THE BALL TO TRAVEL SLOWLY DOWNSTREAM AT A STEADY RATE* (Maintenance Equipment Operator). This procedure produces the best cleaning action. Ineffective cleaning results if the ball travels too fast. If you are short of head pressure, holding or stopping the ball travel and then releasing it at intervals will increase the head pressure and spinning action. This also causes the jet stream around and in front of the ball to break up debris deposits. The ridges of the grooves in the ball's surface also will give a scouring action to the interior of the sewer.

If the ball suddenly stops, this is an indication of a large deposit, that sufficient material has built up to stop the ball travel, the ball has hit a bad tap, or a crushed or offset pipe. By pulling back on the tag line a short distance, the ball will "egg shape" causing first, a vacuum in front of it and then a sudden flushing action. This "bouncing" of the ball sometimes has to be repeated several times to remove large or stubborn deposits. If a deposit can't be removed or reoccurs frequently, complete a form requesting that the line be televised.

As the operation continues, the debris to be removed will start appearing when the ball gets within 20 to 25 feet of the downstream manhole. When the debris does begin to appear, an operator should be in the downstream manhole with a short handled shovel, shaped to fit the channel, so that the operator can remove the debris as it appears. The accumulation of the debris may be slowed down by holding the tag line and stopping the forward progress of the ball. By releasing the ball a little at a time, the operator in the downstream manhole is able to remove all of the debris as it appears. *DO NOT USE A SAND TRAP OR OTHERWISE RETARD THE FLOW IN THE DOWNSTREAM MANHOLE* because a trap can hinder the effectiveness of the balling operation.

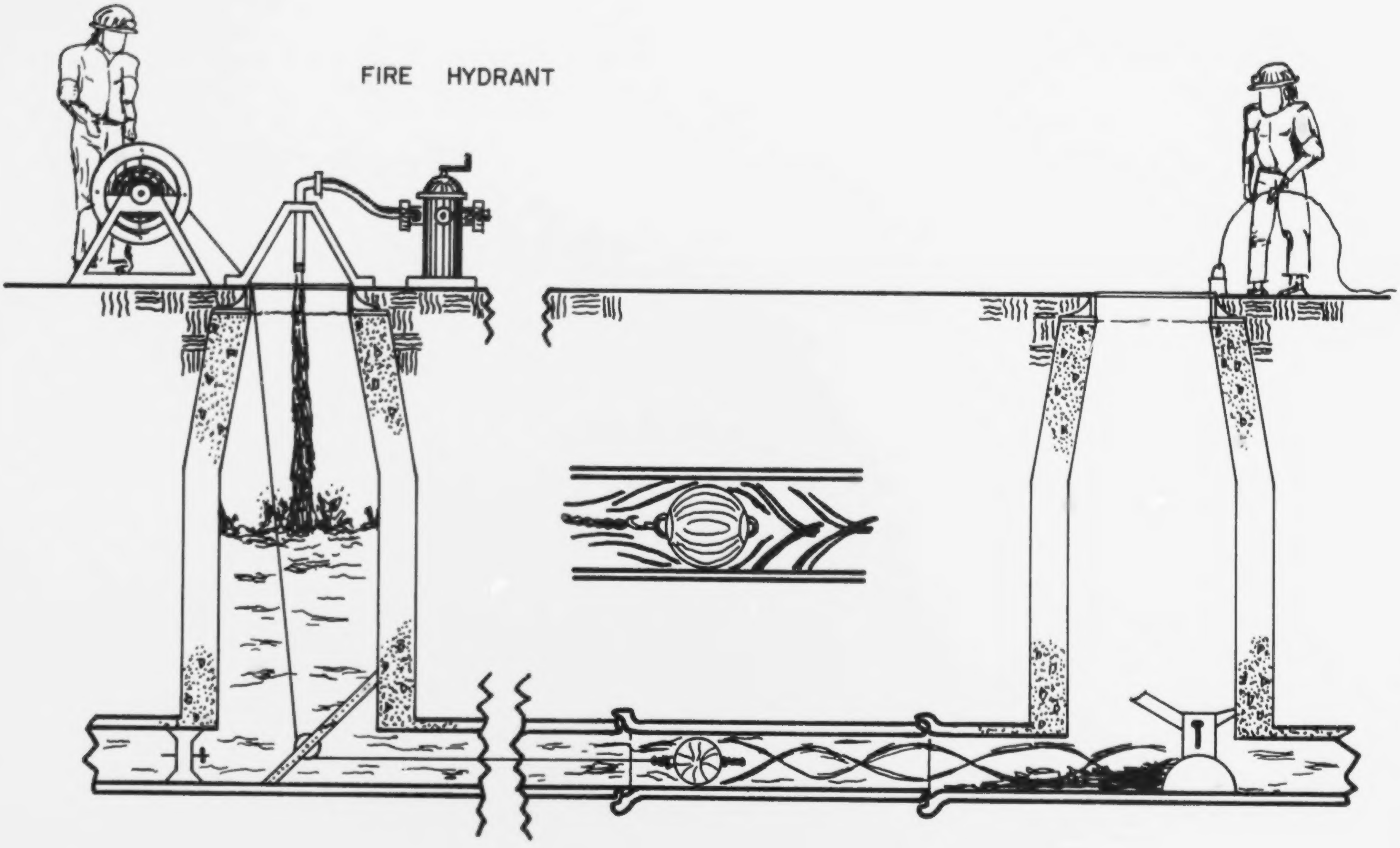

FIRE HYDRANT
302
303

Fig. 6.9 Balling operation

When balling a sewer that contains considerable debris and slimes that are producing hydrogen sulfide (rotten egg smell), it may be desirable to use a sand trap. This is better than having an operator in the manhole shoveling debris and being exposed to the hydrogen sulfide which is being pushed down the sewer ahead of the balling operation. If a sand trap must be used (as shown in Figure 6.9), the pressure head behind the ball will have to be raised to maintain the cleansing velocity around the ball.

The information and procedures given for balling also can be used for cleaning with tires (Figure 6.10). When a flushing action is needed in a sewer, give slack to the tag line and the tire will tip forward from the top, thus releasing water. Pull back on the tag line and the tire will return to an upright cleaning or flushing position. Tires are not as flexible as balls and cannot be inflated or deflated like a ball for proper fitting in a pipe. Tires used for cleaning sewers can be made up in an agency's shop.

Constant communication between the reel operator (Maintenance Equipment Operator) and the operator removing material from the bottom of the downstream manhole (Maintenance Man I) relayed through the operator above the downstream manhole is essential for the safety of the operator in the downstream manhole. If auxiliary water is being used, shut this water off at the control valve once debris starts arriving in the downstream manhole. The downstream operators should shovel this material into a bucket and lift the bucket from the manhole with a rope as quickly as possible so the operator can continue.

Continue balling and watch and listen for the ball at the downstream manhole. Keep it from entering the manhole until all remaining material has been removed. A strong shovel or bar can be placed over or across the incoming line to hold the ball back. When the manhole is clean, the ball can enter the manhole. If the tag line is of sufficient length to reach the next downstream manhole, insert the ball in the downstream line, and the operation can continue without another complete set up. The one crew needs only to move to the next lower manhole and get ready to remove debris when it starts arriving.

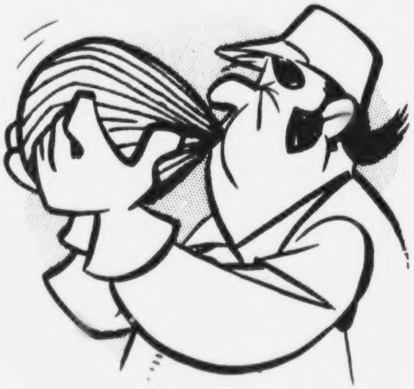
When the operation is completed, disconnect the ball and rewind the tag line on the storage reel. If using a cable, attach a weight to the end of the cable to prevent twisting. With the removal of the plugs and lower guide roller, you are ready to move on downstream. The debris should be loaded on the truck and disposed of at a disposal site. The manhole cover rings should be cleaned and the covers replaced and inspected for proper seating. Clean the street.

Communications between crew members can be improved with the use of hand held radios or walkie-talkees, sound powered telephones or effective hand signals. Page 286 illustrates hand signals used by crews cleaning sewers.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 352.

6.21H Why must a sewer ball be properly inflated?

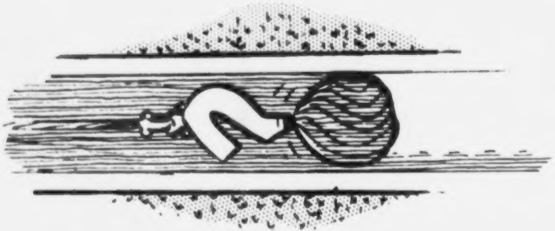


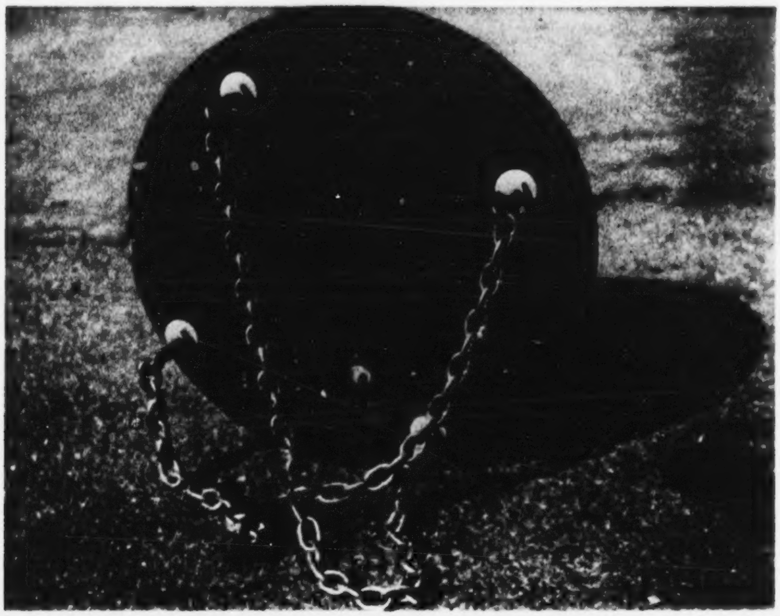
6.21I How is the material cleaned from the sewer by the ball removed from the collection system?

6.21J How should the ball move downstream?

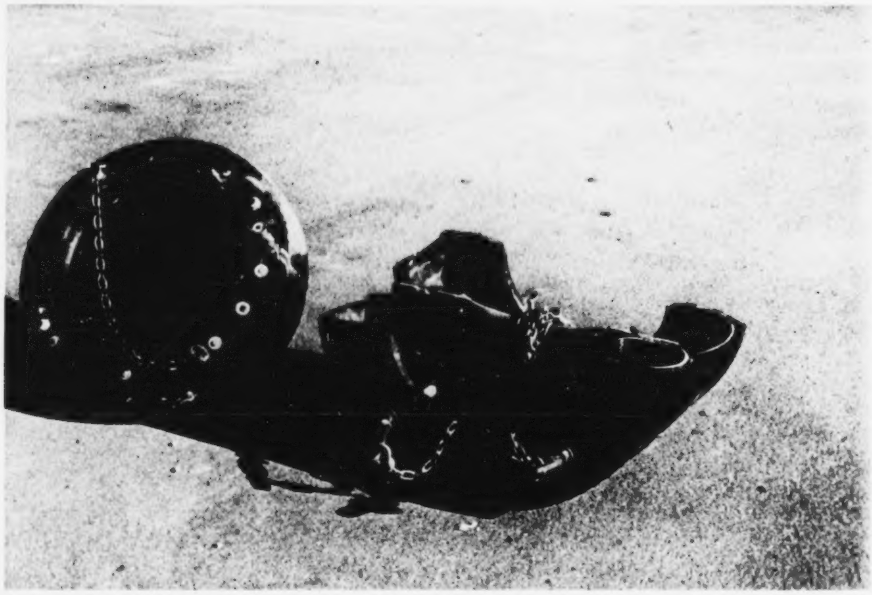
6.21K What could cause a ball to stop moving down stream?

6.21L How could you determine what caused a ball to stop moving downstream?





Typical tire used for cleaning lines from 8 through 48 inches. Photo shows side of tire where head develops. Chain bridle is used for controlling tire.

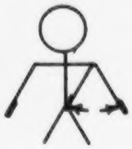


Tire on left shows front of tire with pickup chain for removing tire from downstream manhole. Tire on right is used to clean lines over 24 inches and is hinged to allow tire to pass through 24 inch manhole frame.

Fig. 6.10 Tires
(Courtesy of Union Sanitary District)

HAND SIGNALS IN SEWER CLEANING

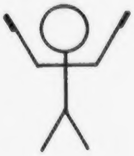
1



ALLOW BALL TO TRAVEL OR TO MOVE

ARM IS SWUNG IN FRONT OR SIDE OF BODY WITH FINGERS EXTENDED

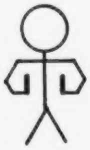
2



STOP OR HOLD

ARMS ARE HELD UP OUTSTRETCHED

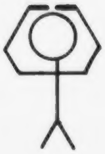
3



ALLOW BALL TO TRAVEL A SHORT DISTANCE

PRECEDED BY TRAVEL SIGNAL — BOTH HANDS ARE HELD APART, PALMS INDICATING DISTANCE FROM 2 FEET TO 6 FEET OUTSTRETCHED.

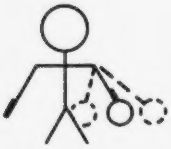
4



BALL HAS ARRIVED — GIVE LINE SLACK

ARMS ARE HELD UP AND OVERHEAD WITH FINGERTIPS TOUCHING.

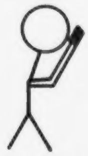
5



BALL IS OFF SNAP REEL IN TAG LINE

HOLD SEWER BALL TO SIDE OF BODY AND SWING.

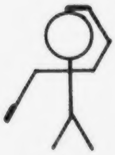
6



BALL IS DEAD — PROBABLY PLUGGED MAIN

HAND OR HANDS HELD AT SIDE OF TILTED HEAD (as in sleeping)

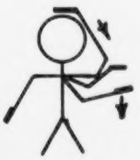
7



MANHOLE IS SURCHARGED OR HAS HEAD OF WATER

HAND IS HELD FLAT TOUCHING TOP OF HEAD

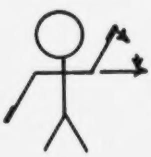
8



SURCHARGED OR WATER HEAD DECREASING

PRECEDED BY HEAD SIGNAL — MOVE HAND AND ARM SLOWLY DOWN.

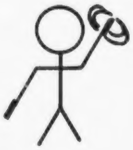
9



UPSTREAM OR DOWNSTREAM DIRECTION

PRECEDED BY TRAVEL SIGNAL — MOVE HAND AND ARM UP ABOVE HEAD AND THEN DOWN POINTING IN DIRECTION OF TRAVEL.

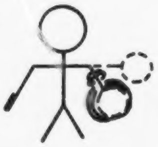
10



TURN ON FULL HYDRANT WATER SUPPLY

ONE ARM HELD OVER HEAD IN CIRCULAR MOTION.

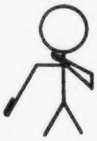
11



TURN ON HYDRANT WATER SUPPLY

ONE ARM IS HELD OUT TO SIDE AND MOVED IN CIRCULAR MOTION (Low for little water — high for more water)

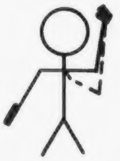
12



TURN OFF HYDRANT WATER SUPPLY

ONE ARM IS BENT SHOULDER HIGH WITH FINGER TIP MOTION CUTTING ACROSS THROAT.

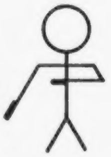
13



DISTANCE — 100 FEET

CLOSED FIST WITH ARM BROUGHT UP TO ABOVE HEAD. (Each raise of fist means 100 feet)

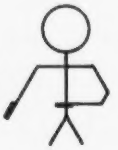
14



DISTANCE — 75 FEET

HAND HELD CHEST HIGH WITH PALM DOWN

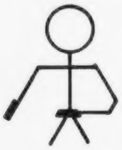
15



DISTANCE — 50 FEET

HAND HELD WAIST HIGH WITH PALM DOWN

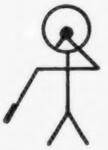
16



DISTANCE — 25 FEET

HAND HELD KNEE HIGH WITH PALM DOWN

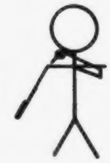
17



HIGH PRESSURE MACHINE — INCREASE WATER PRESSURE

WITH MOUTH OPEN — THUMB MOTION TO MOUTH

18



HIGH PRESSURE MACHINE — DECREASE OR CUT WATER PRESSURE

THUMB MOTION ACROSS THROAT

6.214 *Precautions and Safety*

Certain precautions have to be taken or at least considered before and during all cleaning operations.

Using water pressure in the cleaning of gravity flow sewers always requires care and judgement with respect to basement fixtures and low elevation homes.

If there is any possibility of the water level behind the ball getting higher than basement fixtures (Figure 6.11), inspect these residences or business establishments for potential problems or use another method of cleaning, such as a high velocity cleaner.

If a stoppage occurs below the ball, it must be cleared as soon as possible to avoid flooding homes or streets. First try to break the stoppage by using the ball. If this doesn't work, use a hand rod, power rodder, or high velocity cleaner at the downstream manhole to clear the stoppage.

As previously outlined, all street work requires safety measures sufficient for the particular conditions involved. Emphasis should be made in getting barricades or warning measures a good distance away from the working areas. Always use flagmen where there is a need to control traffic (see Section 4.3, "Routing Traffic," and Sectrion 4.4, "Manhole Hazards").

If a sewer ball becomes stuck, try to work it loose without breaking the cable. A high velocity cleaner (Section 6.22) inserted in the downstream manhole hole may be able to go up the line and knock the ball loose. Another approach is to use a power rodder and try to puncture the ball. When a ball becomes stuck, be sure upstream homes don't flood while you are working the ball loose.

6.215 *Records*

See Section 6.18, Records.

6.216 *Summary*

The balling method of cleaning is a relatively easy procedure, is very effective, and uses a minimum amount of equipment. Common sense measures of operations are involved and techniques can be developed and used to overcome problems common to this method of cleaning.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 353.

6.21M What would you do if a stoppage occurred below the ball?

6.21N What safety precautions should be taken during a balling operation?

6.22 High Velocity Cleaning Machines

The use of water pressure to clean sewers dates back to the early 1900's; however, this method has been improved upon with the present day high velocity cleaning machines.

The fundamental idea of using a self-propelling nozzle on the end of a hose is still used. Instead of using a fire hose hooked to a hydrant, we have self-contained portable equipment, hoses and nozzles that not only do a better job, but do it faster and cheaper.

High velocity cleaning machines are used to:

1. Open stoppages,
2. Remove grease,
3. Clean lines of debris, and
4. Wash manholes and wet wells.

Although the design of the high velocity cleaning machine will vary with different manufacturers, they are essentially all the same.

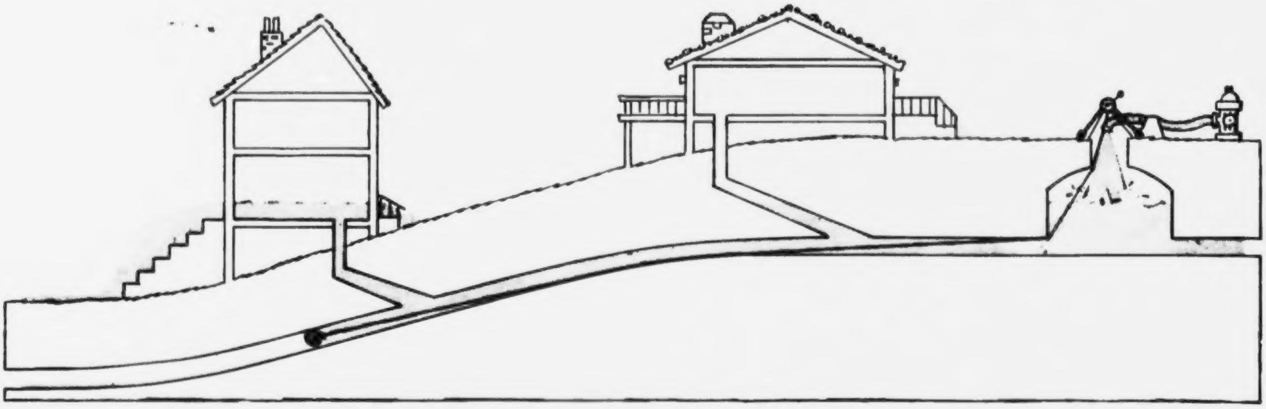


Fig. 6.11 How to flood a basement

6.221 Manpower and Equipment

These machines consist of a water supply tank usually with a capacity of 1,000 gallons or more, a high pressure water pump and an auxiliary engine for its operation (Figures 6.12, 6.13, 6.14 and 6.15). The unit will have a powered drum reel capable of holding at least 500 feet of hose, usually one-inch ID. To the end of this hose, a nozzle will be attached which will create water velocities that do the cleaning. Accessories are varied and new tools continue to be developed as well as techniques in their use. Among these accessories for this cleaning method will be a nozzle with rear jets only, a nozzle with rear jets and one forward jet, a dual nozzle, a hose roller or hose guide, and a wash-down gun or nozzle. In addition, sand or debris traps, manhole shovel, debris bucket and hand line, and a manhole lifter are essential tools too. Machines with 1-1/4 inch ID hose and special nozzles can be used to clean debris from larger lines and storm sewers.

For purposes of discussion, we will consider the use of a truck- mounted, high velocity cleaning machine. These units are available as trailer mounted types as well, but they usually have less water tank capacity.

We will concentrate on the cleaning of sewers with 6 to 15-inch diameters; however, because of the design of this equipment, it is also effectively used for street cleaning, backup fire control equipment, chemical spraying, and watering landscape along streets and in parks (Figure 6.14).

The machine is operated by one operator (Maintenance Equipment Operator). This operator will need help in order to be notified when the cleaning nozzle has reached the upstream manhole, and when the grit and debris are removed from the working manhole. *SAFETY REGULATIONS REQUIRE TWO OPERATORS TOPSIDE WHEN AN OPERATOR IS IN A MANHOLE.*

A foreman can be called to assist a two-operator crew whenever someone must enter a manhole or other enclosed space. Additional assistance may be needed for traffic control. Manpower requirements include:

1. Maintenance Equipment Operator, and
2. Maintenance Man I (one or two operators).

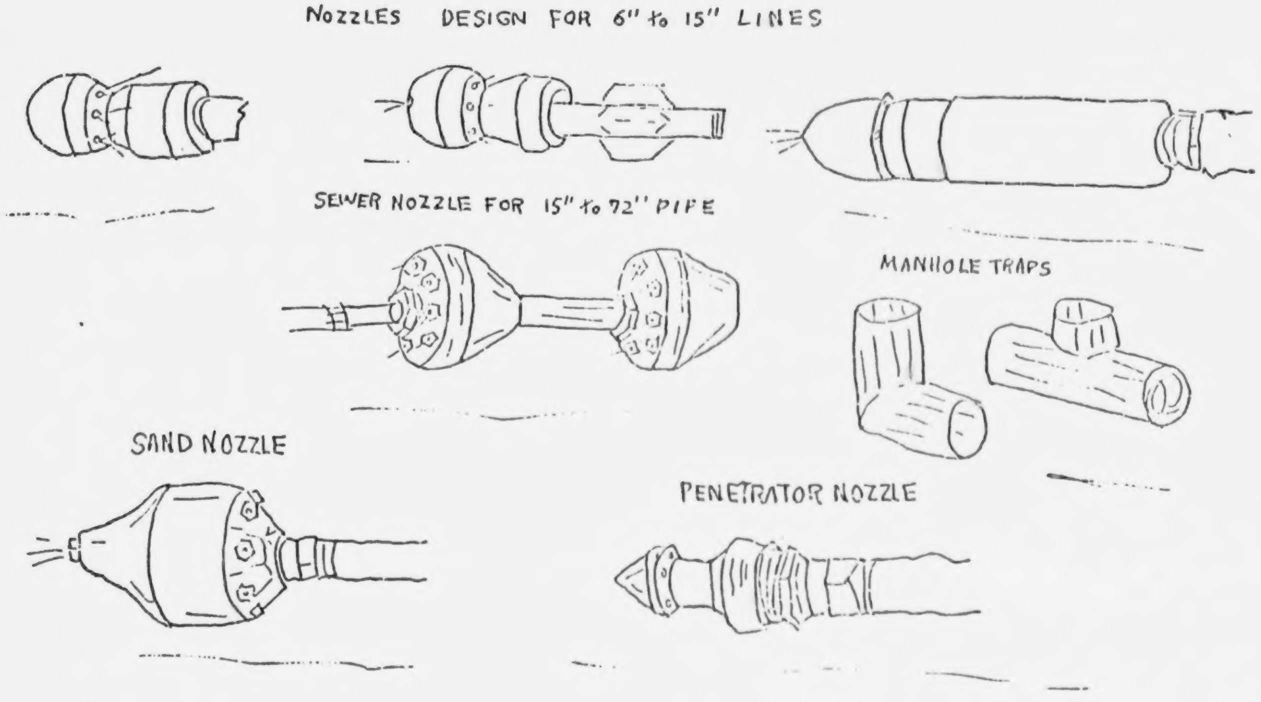

NOZZLES DESIGN FOR 6" to 15" LINES
SEWER NOZZLE FOR 15" to 72" PIPE
MANHOLE TRAPS
SAND NOZZLE
PENETRATOR NOZZLE

Fig. 6.12 High velocity cleaning equipment

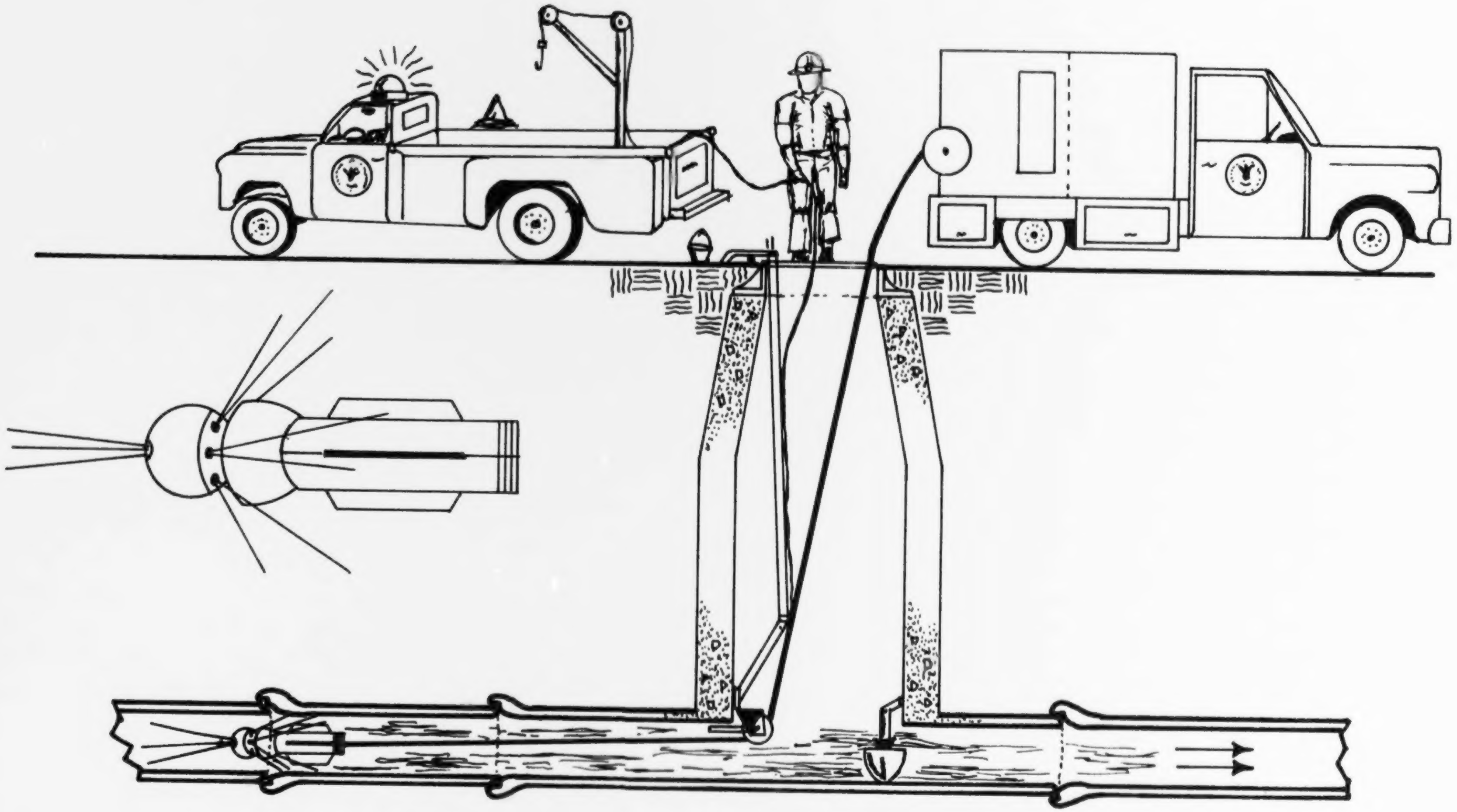
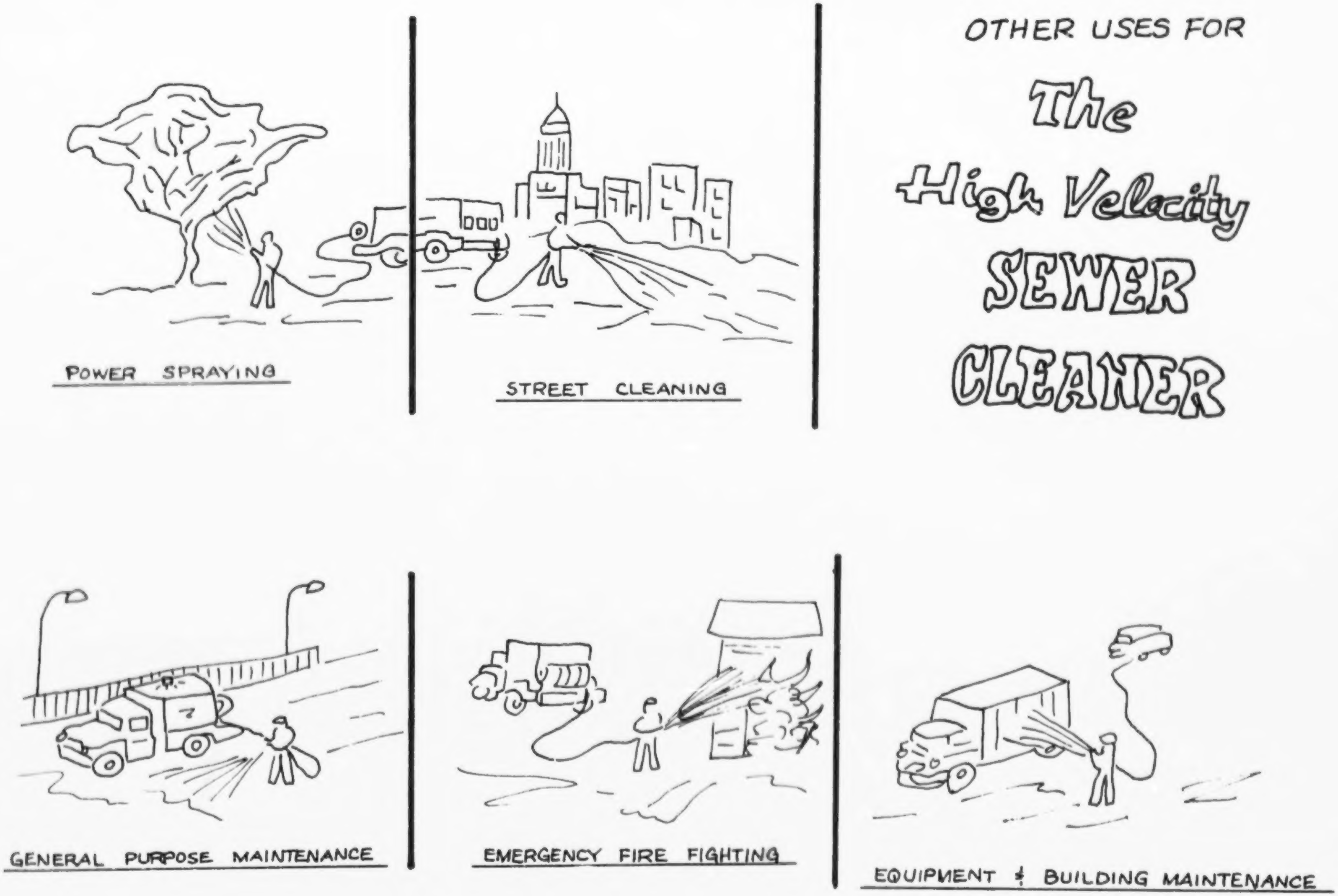


Fig. 6.13 High velocity cleaning operation


OTHER USES FOR
The
High Velocity
SEWER
CLEANER
POWER SPRAYING
STREET CLEANING
GENERAL PURPOSE MAINTENANCE
EMERGENCY FIRE FIGHTING
EQUIPMENT & BUILDING MAINTENANCE

311

Fig. 6.14 Uses of high velocity cleaner

312

The rearward thrust of high pressure water forces the nozzle through the sewer pipe. As the hose reel is rewound, the high pressure water scours the pipe, backflushing the debris to the inlet, where it is removed by the Vactor intake pipe.

The removed material is conveyed by air into the debris box on the truck, where air is separated from dirt and fine dust by centrifugal separators built into the box. Clean air enters the compressor and discharges to atmosphere.

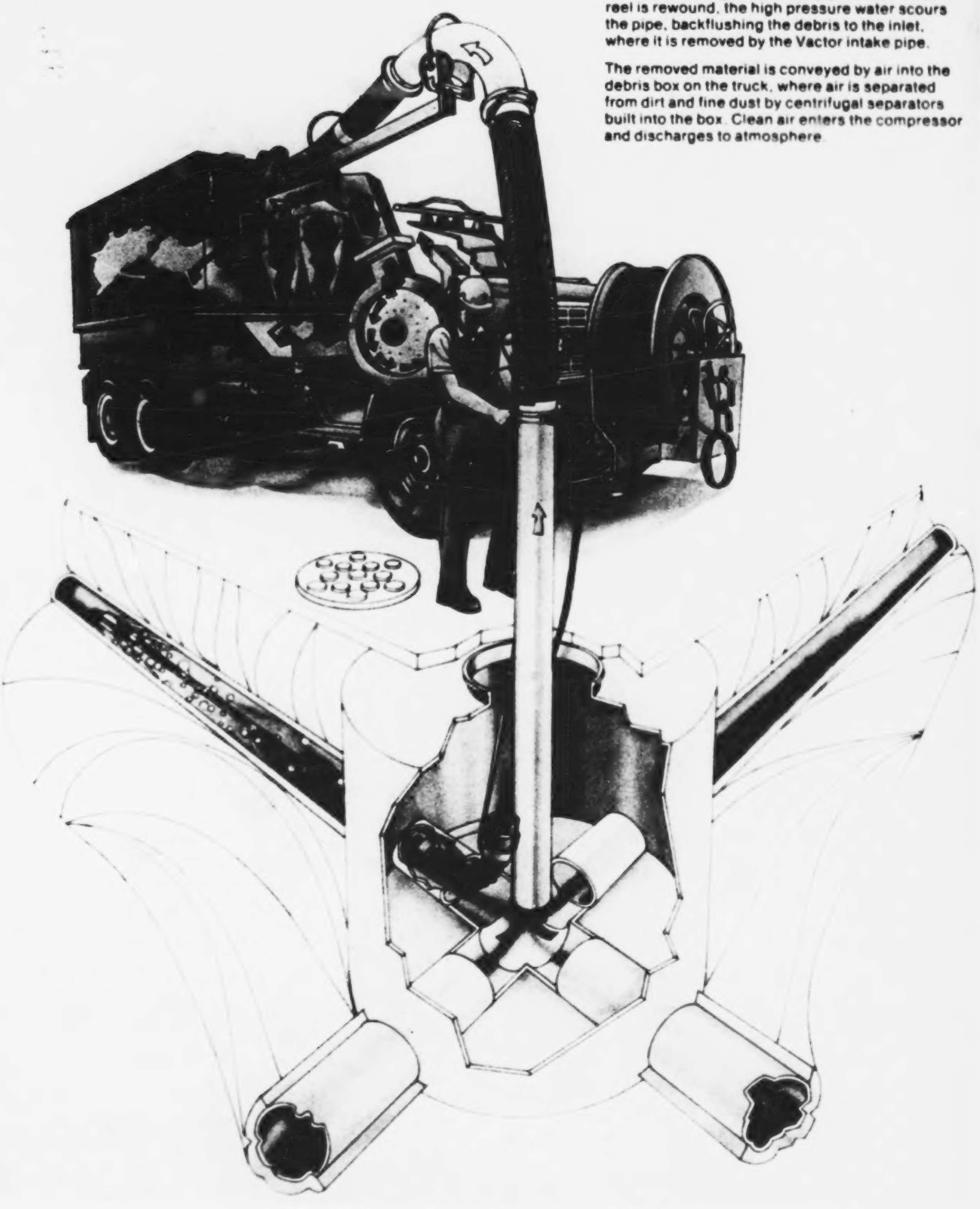


Fig. 6.15 High velocity cleaner with vacuum device for removing grit and debris

(Copyrighted material reprinted with permission of Peabody Myers Corporation)

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 353.

6.22A What are the uses of high velocity cleaning machines?

6.22B How do high velocity cleaners clear sewers?

6.22C How many operators are required to operate a high velocity cleaning machine?

6.222 Equipment Set Up

Because this piece of equipment is a self-contained mobile unit and this method of cleaning smaller sewers is relatively fast, several set ups will usually be made in the course of a day's work.

Basic safety measures still apply, since for the most part this equipment will be set up in the street and traffic conditions must be considered. See Section 4.3, Routing Traffic and Section 4.4, Manhole Hazards, for safe procedures.

TRAFFIC ROUTING
HI! PLEASE TURN BACK AND REVIEW SECTION 4.3 ON PAGE 116

MANHOLE HAZARDS
HI! PLEASE TURN BACK AND REVIEW SECTION 4.4 ON PAGE 124

Fill the water tank from a fire hydrant close to the area where you will do the cleaning. A 1,000-gallon tank full of water weighs 8,340 pounds plus the weight of the tank and truck. Even with baffles in the tank, sharp turns or quick stops can create driving hazards.

When using a fire hydrant, attach a gate valve on the discharge line to regulate flows. *NEVER* throttle or control flow from a fire hydrant with the hydrant valve because this could damage the hydrant valve. When filling a water truck, you must have an air gap between the discharge line and the top of the water tank.

The machine will be equipped with a length of fire hose and an approved hydrant wrench. If the amount of water used is to be recorded, an approved meter also will be part of the equipment.

If a given area or subdivision is to be done completely, start at the top or highest point in the collection system. Whether routine cleaning or spot cleaning, position the high velocity cleaner hose reel over the center of the downstream manhole.

Select the nozzle to be used for this size. The angle of the rear jets vary from 15 to 30 degrees. Usually, the smaller the pipe, the less angle needed. Experience will teach the operator the right tool and technique. Test the manhole atmosphere for sewer gas (see Section 4.4, Manhole Hazards). Install the proper size sand or debris trap in the downstream manhole. Start the auxiliary engine; turn the reel directional control to "out"; and using the reel speed control, lower the hose and cleaning nozzle into the manhole. Direct the nozzle upstream in the line leaving a sag in the hose. The hose guide or roller is usually put into place after the hose has started up the line. The hose needs freedom at this point since the water pressure that forces water at a high velocity out of the rear orifices gives the jet propulsion action that moves the nozzle up the line. The hose guide should not obstruct this first start of the operation. The cleaning operation should be ready to begin.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 353.

6.22D When a high velocity cleaning unit is set up in a street, what measures should be taken to warn traffic?

6.22E Why should the water tank be filled close to the working area?

6.22F Where should you start to clean a given area of subdivision?

6.22G Which direction does the nozzle go in the sewer?

6.223 Cleaning Operation

Turn the water valve on and start the high pressure pump. Water now is being pumped through the hose and cleaning nozzle. With an increase in pump speed, sufficient water velocity will build up to propel the nozzle up the sewer.

An experienced operator is the best person to teach you how far to go into the sewer. Often it is possible to go several hundred feet, but it is not always safe to do so unless a history of this part of the collection system is known. First try 50 feet to check the situation in the sewer (Maintenance Equipment Operator). In any case, if the hose suddenly slows or stops, don't try to go farther. By increasing pressure you may be able to go farther, but don't do it before determining how much material is in the line.

At this point, with the hose roller in place, turn the reel directional control to "in" to return the nozzle. Increase engine speed to obtain approximately 1,000 PSI or the proper rating of the particular unit.

With the reel speed control, slowly start the hose reeling in until the nozzle is just ready to come back into the manhole. The amount of material you have brought back will determine how far and how fast subsequent runs can be made. Repeat this operation until the upper manhole has been reached and no more material is brought back.

During this operation several items may have to be considered and done. If this is a normal operation of routine cleaning, perhaps the entire line from manhole to manhole can be cleaned without enough material building up in the working manhole to make removal necessary until the job is finished.

On the other hand, it may be necessary to clean out the channel after each "pull" if there is a lot of debris in the line. When loosened materials build up to the point of overflowing the debris trap, pull the hose and nozzle out of the manhole. Stop the pump until after the debris is cleared.

Retest the manhole atmosphere for sewer gases to be sure the ventilation procedures are effective. If excessive odorous or hazardous gases are present, a self-contained breathing apparatus may be necessary in addition to ventilation. Have two operators standing by topside. Allow an operator properly equipped with a safety harness to enter the manhole and shovel the debris into a bucket (Maintenance Man I) which in turn is pulled to the surface with a hand line (Maintenance Man I). Some high velocity cleaners have a vacuum device which removes grit and debris from manholes without anyone having to enter a manhole (Figure 6.15).

MANHOLE HAZARDS
HI! PLEASE TURN BACK AND REVIEW SECTION 4.4 ON PAGE 124

During the cleaning operation, care has to be taken to keep the nozzle moving and pump operating at all times. This is especially true in small lines since you do not want to cause a stoppage. A stoppage can occur if you try to go into the line too far at a time and bring back so much material that the nozzle cannot move it downstream fast enough. The smaller lines then quickly fill with water and this in turn goes up the building service lines. If this happens on shallow lines, home damage may result from flooding. Always watch the flow coming into the working manhole. If this flow should stop, a stoppage has developed in the sewer. Pull the hose and nozzle out at once and start over. If the nozzle hits an obstruction and stops, pull the nozzle back to clear the line and then run the nozzle into the obstruction again.

The exact distance the cleaning nozzle has moved up in the sewer must be known at all times. Most machines are equipped with a footage meter; but if not, have some identification — a hose coupling or so many wraps of hose, so as to give an estimate of where you are in the sewer. If you know the distance between manholes, the footage counter will allow you to make the final run without someone (Maintenance Man I) being at the upper manhole.

The high velocity cleaning machine also may be used for stoppages in sewers. Set up is the same as routine cleaning. A nozzle with a forward jet as well as rear jets may be used. This forward jet provides a cutting action ahead of the nozzle. Also the debris trap would be replaced perhaps with a special fork or pole to allow the free flow of wastewater when the stoppage if broken. Large pieces of solids are caught without causing the working manhole to back up.

Upon contact with the stoppage, if the nozzle will not penetrate the stoppage, pull the hose back a few feet by hand and let go. The nozzle will shoot forward quickly and give a pounding effect on the stoppage. When it breaks loose, retrieve the hose and nozzle quickly. After the line returns to normal, reclean the line completely. Inspect the upsteam manhole and flush with the wash-down hose and wash the street free of any overflowed wastewater and solids, disinfect and complete whatever cleanup is needed. Disinfection can be accomplished by the use of a hypocholorite solution.

The high velocity cleaning machine is quite effective in cleaning inverted syphons and easement areas. Special rollers are available where the truck cannot be positioned over the manhole. Remote control equipment is available if practical.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 353.

6.22H How often should the nozzle go up the sewer and be brought back to the downstream manhole?

6.22I What is done when the loosened materials build up and overflow the debris trap?

6.22J Why must the nozzle be kept moving at all times?

6.22K What should be done if flow stops in the working manhole?

6.22L How are high velocity cleaning machines used to clear stoppages?

6.224 Precautions and Safety

Although some of the precautions of operation have been given, there are others which soon become obvious. One of these is cleaning from a manhole to a cleanout. Most often the cleaning nozzle will stop at the bottom of the cleanout. On short runs, however, it is possible to have enough speed and thrust that the nozzle will go up to the street surface and even knock small cleanout covers out of place. When cleaning up to a cleanout, there is also the chance of getting the nozzle stuck. If this should occur, shut the machine off, pull the cleanout cover and dislodge the nozzle with a long rod or pole.

If fresh soil or parts of the sewer pipe are washed down into the lower manhole when pulling the nozzle back, stop the operation. Continued attempts to clean the sewer could result in a large hole developing under the street and the eventual collapse of the street into the sewer.

While cleaning, so much material can build up below the nozzle that you cannot pull the nozzle through under pressure. Stop the pressure and pull the nozzle back through the stoppage "dead" (without water flowing out the nozzle). If this fails, try to get the nozzle to the upstream manhole and take it off, thus allowing only the hose to be pulled back through the stoppage to the downstream manhole. Replace the nozzle and go back up the line after the stoppage.

Often a bend in the line will prevent you from pulling the nozzle back under full pressure. The more pressure at the nozzle, the stiffer the hose becomes. Reduce the pressure or even turn it off for a short distance until you are past the bend.

In cold weather, particular precaution has to be taken to keep the equipment from freezing. Special attention should be given to the high-pressure pump to make sure that it is properly drained. If the machine is equipped with a canopy over the engine and pump area, the areas can be separated by a curtain and a small electric heater can be left inside the pump area overnight or when not in use during freezing weather. Another approach to prevent freezing during cold weather is to install a piping system which allows water to circulate through the pump *AND HOSE*. Be sure to include the hose because some water always remains in the hose, no matter how much time and care are taken to drain the hose.

Do not allow an inexperienced operator to operate the machine alone. Personal safety is not so much a problem because of the design of the machine; however, costly problems can develop if care is not given to existing conditions in the collection system and those that the cleaning operation can create. Caution and experience are required to prevent "blowing toilets" with a high velocity cleaner.

Also, do not sacrifice clean lines for footage. This equipment is capable of doing a thorough job of cleaning. There is the tendency to consider the line to be clean when perhaps you are running low on water. Take the time to get another load and make sure the line is properly cleaned.

Some agencies use a TV camera to televise the sewer while using a high velocity cleaner. This approach has been very successful to remove small patches (two to three feet long) of heavy grease. Without the TV camera the nozzle would not have been stopped at the grease patch long enough to remove the grease. This same approach can be used to remove roots using a high velocity cleaner rather than simply having large footage production per day and clean roots.

6.225 Records

See Section 6.18, Records.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 353.

6.22M What precautions should be taken when cleaning from a manhole to a cleanout?

6.22N What would you do if so much material built up that the nozzle could not be pulled back to the downstream manhole?

6.22O What precautions must be taken during cold weather?

6.23 Flushing

Flushing (Figure 6.16) is another method of hydraulic cleaning and is occasionally used at the beginning of the collection system where low or sluggish flows permit the deposition of solids. This procedure may be effective in removing floatables, but not grit and other heavy solids. Flushing also is used with mechanical clearing operations such as power rodders and bucket machines. High velocity cleaners and balling do a much better job of cleaning sewers than flushing.

During the flushing operation, observe the flow characteristics in the sewer — is the flow through the manhole slow or sluggish? A partial stoppage may restrict the flow of the flushing water being discharged into the sewer. *OBSERVATIONS OF LOWER THAN EXPECTED FLOWS AT A DOWNSTREAM MANHOLE THUS INDICATE THAT THE UPSTREAM SEGMENT OF THE LINE REQUIRES ADDITIONAL CLEANING.* As the water flows, a physical and visual check can be made of the material in the line such as sand, grease, and debris. *THIS OBSERVATION ALSO MAY DICTATE THAT MORE EXTENSIVE CLEANING IS NEEDED.*

Stoppages are commonly located during the flushing operation. Material often will have built up to the point of causing a stoppage when just a sudden charge of water will break it loose, thus clearing the line. Having this large amount of water passing through all at once has a definite control on rodents and insects.

Also cleaning the manholes with water pressure eliminates manhole shelf build up of street dirt and debris. Cleaning the manhole with water pressure, combined with the flushing action within the sewer, will minimize the build up of sulfide and slime in the line. This is one of the primary problems of line decay and replacement. Flushing may be used in steep hills where the use of balling or high velocity cleaners creates a high risk of flooding homes when not properly operated.

This method of cleaning in smaller collection systems usually must be repeated frequently to prevent many routine problems, but requires large volumes of water. Before starting a flushing operation, notify the water department whose hydrants will be used as a source of water. The opening and closing of hydrants must be done with great care because improper procedures could create water quality problems in the water distribution system. Also notify the operator of the downstream wastewater treatment plant whenever larger than normal flows can be expected at the plant.

6.231 Manpower and Equipment

Because of the small amount of equipment and number of operators involved in flushing, the actual cost appears attractive. However, the procedure may not be cost effective because of the limited cleansing action from flushing.

A tank truck with a capacity of 1,500 to 2,000 gallons is needed. The truck should be equipped with a reel for holding approximately 100 feet of 1-inch ID hose and a pump to give sufficient pressure to do an effective job of manhole cleaning. The nozzle type may vary from an adjustable model to a plain piece of pipe reduced to give a good cutting action. A ¼-inch pipe nipple brazed onto a 1-inch female hose fitting provides a good stream (if the pump provides 25 to 30 psi in the line) for hosing down the manhole barrels and a shelf prior to flushing the line.

A 2½-inch or larger gravity discharge line from the bottom of the tank on the truck should be provided to permit a large flow of water. Location of the line must be convenient for the truck driver to position it over the manhole. If possible, the ideal location is just ahead of the left front wheel. This line should be equipped with a quick opening, full flowing valve. A short piece of old inner tube fastened just above street level will help direct the flow of water into the manhole if positioning is difficult.

The tank truck equipment should include a good filler hose, usually a short length of fire hose to reach from a fire hydrant to the top of the tank's filling hatch, hydrant wrench, water meter, air gap device, and manhole lifter. Some communities require a 2½-inch water meter so that they can pay for the water used for flushing.

A debris bucket, rope and manhole shovel are other pieces of essential equipment, plus the usual safety equipment (Chapter 4, Section 4.3, Routing Traffic, and Section 4.4, Manhole Hazards). The equipment and tools for this operation should be arranged on the tank truck in such a manner as to be handy and within the limits of space available.

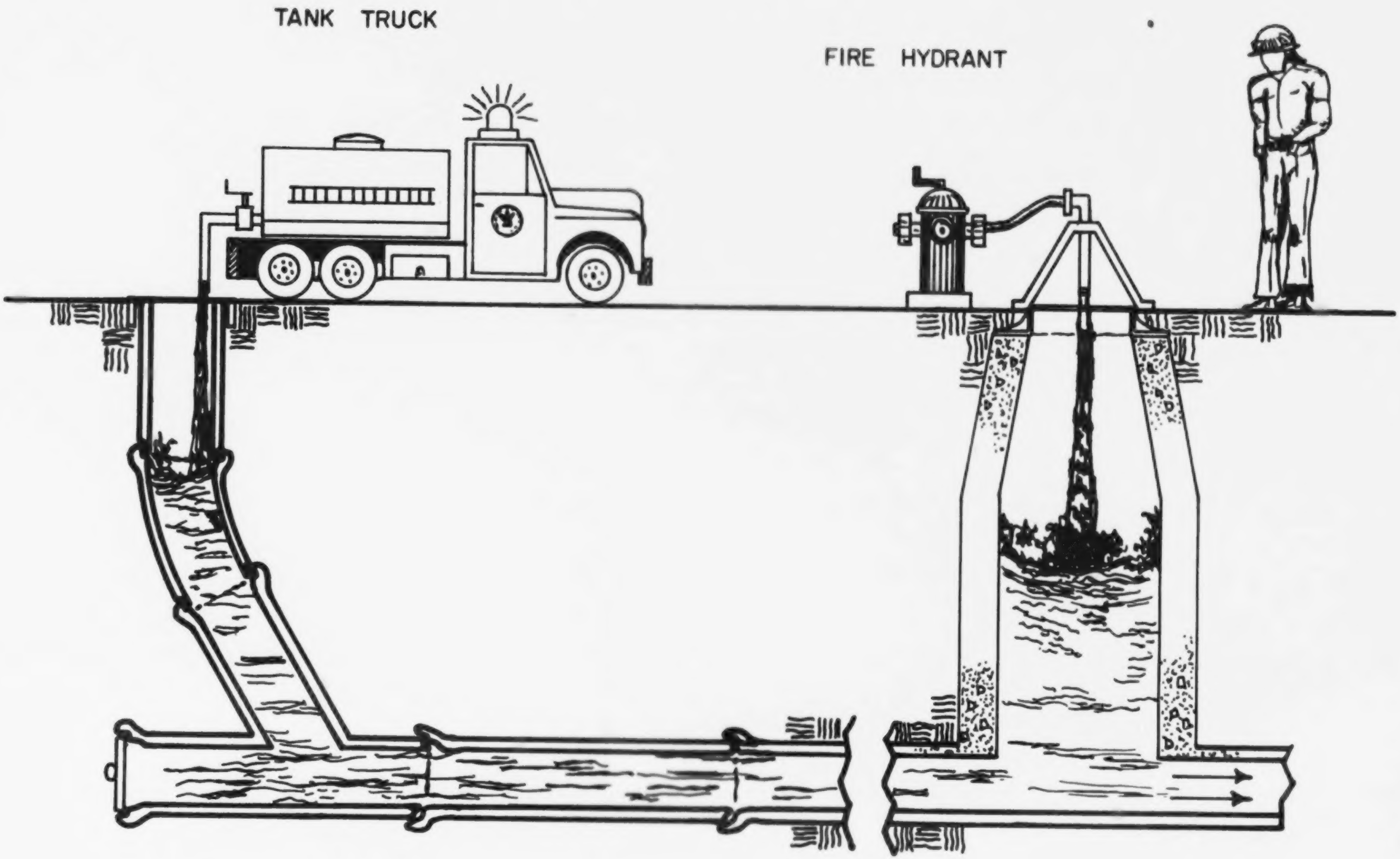

TANK TRUCK
FIRE HYDRANT

Fig. 6.16 Flushing operation

317

318

Two operators are needed and they should be clothed with hard hats, red vests, and gloves. Typical street traffic should be expected but keep in mind, too, you probably will not be long at one manhole. Manpower requirements are:

1 Maintenance Man I, and

1 Maintenance Man II.

If the flushing crew consists of only two operators, neither one should ever be allowed to enter a manhole. Flushing crews usually have to enter every third or fourth manhole to remove debris. Whenever an operator enters a manhole for any reason, two operators must be topside at all times. The third operator could be a Maintenance Man II or another operator that could be readily available when needed.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 353.

6.23A Where in the collection system is flushing commonly used to clean lines?

6.23B What does lower than expected flows at a downstream manhole indicate during a flushing operation?

6.23C How does flushing help to control rodents and insects in sewers?

6.23D What are the manpower requirements for a flushing crew?

6.232 Equipment Set Up and Flushing

Determine whether to use a tanker or fire hydrants or both as a source of water for the flushing operation. Start the flushing operation at the extreme upstream end of the collection system.

Place the water line over the manhole and protect the equipment and working area with sufficient safety cones, flags, and warning signs. Follow the directions in Section 4.3, Routing Traffic and Section 4.4, Manhole Hazards.

TRAFFIC ROUTING
HI! PLEASE TURN BACK AND REVIEW SECTION 4:3 ON PAGE 116

MANHOLE HAZARDS
HI! PLEASE TURN BACK AND REVIEW SECTION 4.4 ON PAGE 124

A good visual inspection should be made of the manhole condition. If the water has been backed up, there will be evidence of debris in the shelf area and high water marks indicated by a grease ring. The general condition of the manhole, by number, should be part of the report and recorded at this time.

The manhole should be cleaned with the pressure hose. Since you will want to get more water and move on as quickly as possible, clean the manhole first. Use a pressure hose to clean the manhole and wash the manhole cover casting, cone, barrel, and shelf of the manhole (Maintenance Man I).

The amount of water you will dump into the line will be related to the amount of flow at the time of flushing. The entire water load may not have to be dumped in one manhole. After you have dumped some of the water, observe if there is any evidence of the water backing up.

If the flushing water backs up into the manhole, stop the addition of flushing water or reduce the application rate to prevent flooding of connected residential and commercial services. Observe the water flowing in the downstream manholes and look for signs of grease, roots, or other debris that are creating the restriction. If the restriction is caused by a heavy deposit of wastewater solids, flushing *MAY* move the cause of the restriction down the line to a manhole where it can be removed or broken up by spraying with the tank washdown hose and flushed on downstream. If the deposit is caused by roots or grease, prepare and submit a note or work order to have that segment of the line cleaned by using the proper equipment to remove the restriction.

Close the manhole and go to the next downstream manhole. Inspect this manhole as outlined above and clean it completely with the washdown hose.

This operation will be repeated from manhole to manhole. As long as heavy flows are observed in the manholes, the operation is progressing satisfactorily. If the flows decrease, look for a stoppage by looking for flows backing up in the upstream manhole. If there is no evidence of a stoppage and flows are declining, more water will have to be introduced to maintain cleansing flows for the flushing operation.

The cleaning at each manhole with a hose takes only a few minutes, but this is the time and place where you should be alert for those items referred to in the beginning of this chapter — foreign material, grease, sand, and roots that can cause problems or indicate problems are occurring.

How many feet of sewers can be flushed by a crew in one day is difficult to estimate because of the many problems of manhole location, traffic conditions, and other obstacles. As much as 20,000 feet or more of sewer and many manholes can be flushed in a day if you do not encounter too many problems. Daily production depends upon the number of manholes that have to be entered and cleaned, plus their condition and location. Whether manholes are located in rear easements and whether flushing can be accomplished by laying a fire hose from a hydrant or from the tank truck to the manhole in a backyard have considerable influence on the time required to flush a line.

6.233 Precautions and Safety

Safety measures need to be followed carefully at all times, from properly protecting the equipment and working area with safety cones to checking manholes for gases found in sewers (toxic and explosive gases and oxygen level).

When flushing, the turbulence many force accumulated gases from dislodged debris or slimes downstream, so care must be taken at all times.

This method of cleaning presents problems very similar to those of balling. Consideration has to be given not to put more water into the collection system than it can handle. Care must be given that a stoppage is not caused which in turn may flood a residence or business. The amount of material and debris being flushed through should not be allowed to accumulate. Care is needed in this respect, especially when first starting a flushing program.

6.234 Records

Since many manholes are going to be opened and cleaned during the flushing operation, there is no better time to make records of defects, leaks, roots, and other problems (see Section 5.3, Inspection of Manholes). In addition, the amount of grease or other material visible also can be recorded. Also see Section 6.18, Records.

6.235 Summary

As mentioned at the outset, flushing can be part of a sewer cleaning operation in conjunction with other mechancial clearing equipment, especially the power rodding machine. The power rodder can cut roots and grease from the walls and joints of pipe, but the removal of that material is dependent upon normal flows unless a flushing unit is used. Flushing is most effective during the power rodder's operation, but can follow at a later time. Flushing is not as effective as balling or high velocity cleaning because sufficient velocities are not developed to move grease, grit, and heavy debris. A flow velocity of 2.5 feet per second will *PREVENT* the deposition of solids in a sewer, but once solids accumulate the flow velocity from flushing is not high enough to *CLEAN* the sewer.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 353.

6.23E Where do you start a flushing operation?

6.23F How is a manhole cleaned?

6.23G What factors influence the length of line that can be flushed in one day?

6.23H What safety precautions must be taken during a flushing operation?

6.24 Scooters

The scooter (Figures 6.17, 6.18 and 6.19) is another cleaning tool found to be very effective for cleaning wastewater collection systems by using water pressure. The scooter is designed to be self-propelled in gravity collection systems and operated similar to a balling operation. The operation is quite simple and again the cost is considerably less than the cost of some other cleaning methods.

Basically the scooter is a framework on small wheels with a circular metal shield at one end which is rimmed with a rubber flange. The top half of the shield is hinged and is controlled by a chain-spring system. The lower half of the shield is fastened with bolts to the front of the undercarriage. The flow of water behind and around the scooter is controlled by hinging the upper half of the shield to the scooter. This allows for hydraulic cleaning action and control of the flow of water in the line at the same time. Smaller scooters may be hinged only where the shield is attached to the scooter.

The scooter is capable of removing large objects and such other material as brick, sand, gravel, and rocks. Scooters are considered more effective in larger lines (over 18 inches) and have been used to remove grease in these lines. Even inverted siphons with angles of less than 22½ degrees can be cleaned with the scooter.

Since the scooter is dependent upon water pressure behind it, caution has to be used where sewers are shallow or there is a danger of flooding homes or business property because of the build up of water in the sewer.

Scooters are available in sizes from 6 to 96 inches. The same undercarriage is used for some of these sizes. For instance, one carriage frame will adapt to shield sizes to clean 8 to 15-inch diameter pipes, and another frame will be used for 15 to 36-inch diameter pipes.

On larger sizes, stabilizing weights are used on the tail section of the carriage frame to counteract the head pressure during the cleaning operation.

The head shield on the larger sizes is designed to hinge into two or three parts. This compensates for the high head pressures when folding the head shield to allow water to pass. A spring-loaded mechanism allows the upper section to fold first, thus releasing the initial pressure. As the head pressure decreases, the middle section can be folded by a continued pull on the shield control cable.

Large units are not only heavy to handle, but difficult to get through small manhole openings. By being able to fold the head shield, the scooter can be installed in most instances without dismantling. In some situations the unit may have to be assembled in the manhole.

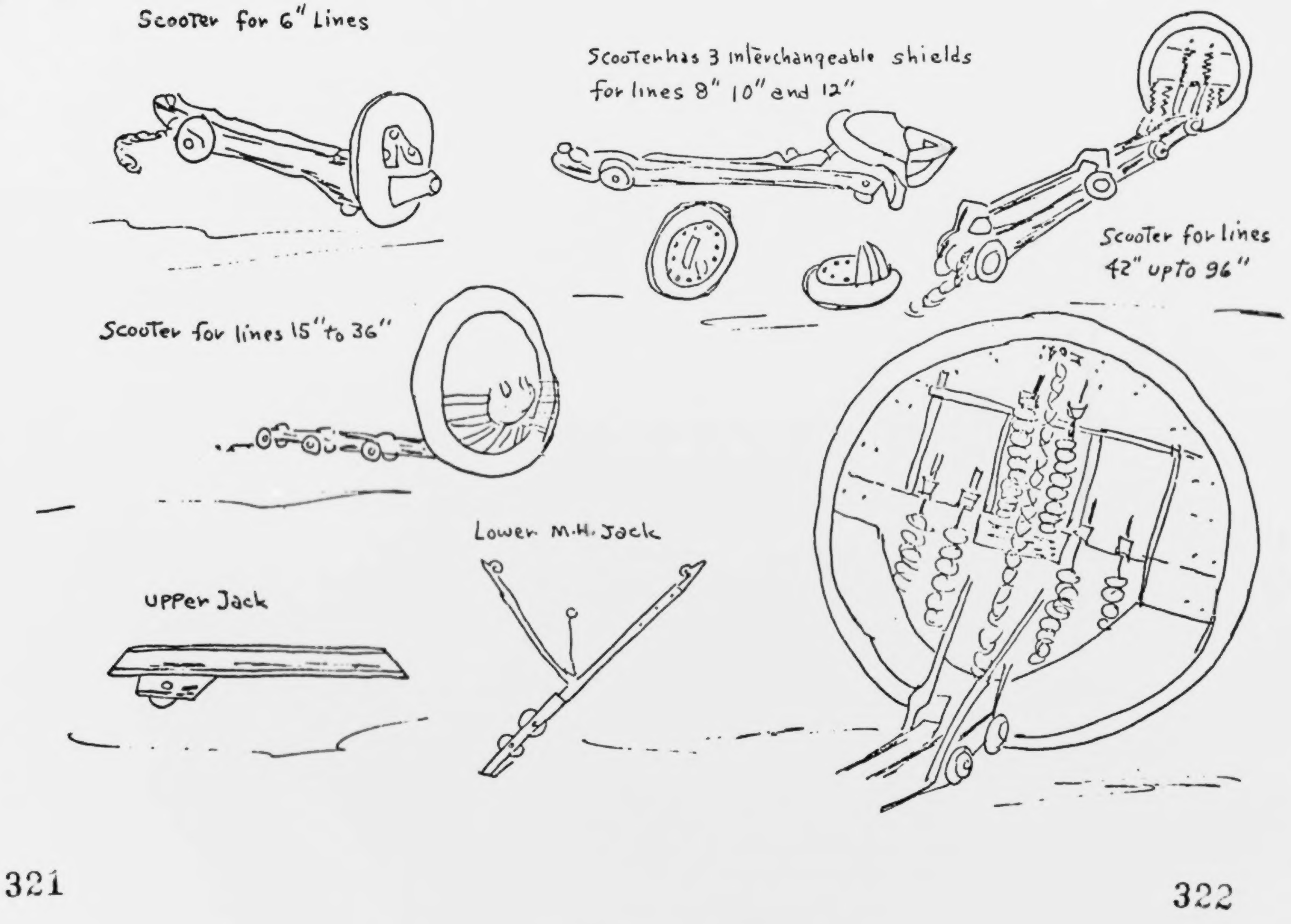

Scooter for 6" Lines
Scooter has 3 interchangeable shields for lines 8" 10" and 12"
Scooter for lines 42" up to 96"
Scooter for lines 15" to 36"
Lower M.H. Jack
upper Jack
321
322

Fig. 6.17 Scooter equipment

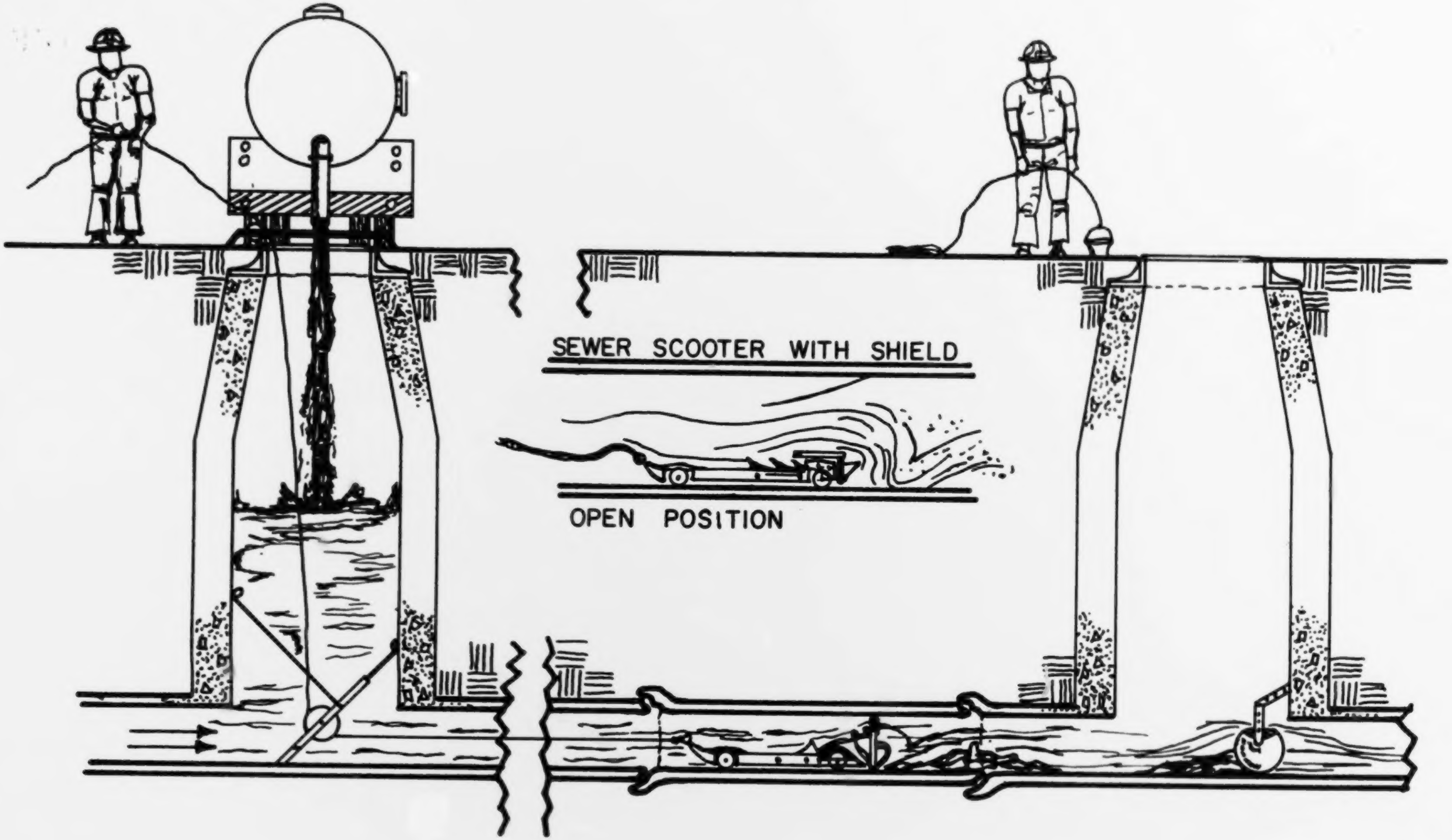
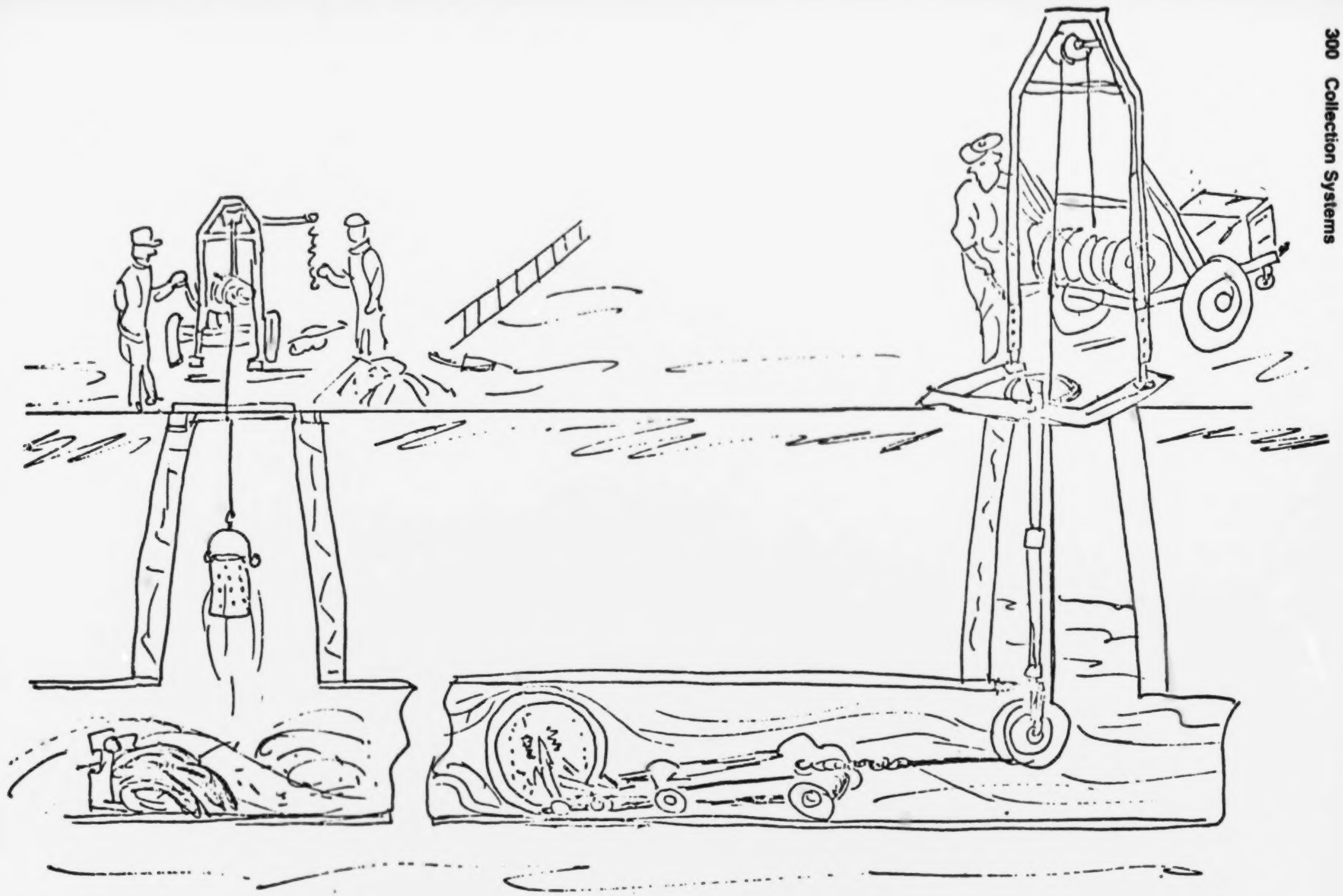

SEWER SCOOTER WITH SHIELD
OPEN POSITION

Fig. 6.18 Scooter operation



325

326

Fig. 6.19 Scooter cleaning larger lines

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 354.

6.24A What causes the cleaning action of a scooter?

6.24B Scooters can be used to remove what kinds of material from sewers?

6.24C What precaution must be exercised when using a scooter?

6.241 Manpower and Equipment

Three operators are needed for safe, efficient operation of the small sizes of scooters (one Maintenance Equipment Operator and two Maintenance Man I). Generally, sewers up to 12 inches in diameter can be cleaned by this method using a hand winch. Fifteen-inch diameter and larger pipe require power drum winch cables. With additional equipment, the operation may require an increase in manpower to handle both ends of the operation.

In addition to the scooter, the following equipment will be needed:

A tank truck (1,000-2,000 gallons)

Pickup truck

Debris traps, control lines, and storage reel

Upper and lower manhole jacks

Roller cable guides

Power drum winch

Safety equipment (See Chapter 4, Section 4.3, Routing Traffic and Section 4.4, Manhole Hazards).

The control line may be plain manila rope or synthetic rope for small lines and steel cable on the power winch for larger lines. The synthetic rope is lighter and stronger than plain manila and will float. Synthetic rope does not mildew and will not have to be dried after use, but it has been known to deteriorate rapidly without warning due to some of the chemicals in wastewater.

The reel for storing the control line should hold 1,000 feet and be portable and easy to coil and uncoil.

When a powered drum is needed for the larger size scooters, a standard bucket machine or balling machine cable drum and winch may be used to control the scooter movement down the line. A powered drum is required because of the heavy force of wastewater built up on the shield. A double drum machine is recommended when using a second cable for tripping the head shield.

These winches are trailer or truck mounted with stabilizer legs and can be installed firmly over the manhole while in operation. Because of the size of the larger scooter and the tremendous pressure of water behind the head shield, strong steel cable is needed in place of rope for both the tag line to the carriage and the shield tipping line.

The manhole jacks or rollers are essential to guide the control lines into the sewer without causing unnecessary wear as the control lines are pulled back and forth in operating the scooter.

The debris trap is installed in the downstream manhole from the working manhole to trap any material worked loose during the cleaning operation. The trap is designed to allow water to pass and to hold back the debris. If the trap hinders the cleansing action around the shield when the scooter nears the trap, it can be removed and the debris shoveled out of the sewer.

Other tools and equipment include a manhole shovel, debris bucket and hand line, boots, gloves, ladder, 100 feet of firehose, hydrant wrench, water meter, air gap device, and manhole lifter.

If the debris removed from the line is to be hauled away by the cleaning crew, perhaps an additional ¾-ton truck will be needed. Often the same truck is used for hauling the cleaning equipment, therefore reducing the overall cost of the operation.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 354.

6.24D How many operators are needed on a scooter crew?

6.24E How does the debris trap installed in the downstream manhole work?

6.242 Equipment Set Up

Before starting the cleaning operation, safety measures need to be taken to warn and control traffic when working in the street and to insure safe working conditions in manholes. Read Section 4.3, Routing Traffic, and Section 4.4, Manhole Hazards, for safe procedures.

TRAFFIC ROUTING
HI! PLEASE TURN BACK AND REVIEW SECTION 4.3 ON PAGE 116

MANHOLE HAZARDS
HI! PLEASE TURN BACK AND REVIEW SECTION 4.4 ON PAGE 124

A suitable debris trap should be installed at the lower manhole so there is no delay in the operation once the scooter is installed and ready for use. Fasten the control rope or cable to the control chain of the scooter and lower the scooter into the manhole. After the head shield end of the scooter is inserted into the downstream line, install the lower manhole jack (Figure 6.17) or control cable guide and secure firmly. This will allow the control cable to take the strain without rubbing on the sharp edge of the pipe during the cleaning operation. If an upper manhole jack or roller is needed, it should be installed next.

During this time the head shield of the scooter will act as a plug and a head of water will start building in the manhole. This can be controlled by pulling firmly on the control line, which in turn will fold the upper portion of the head shield and allow the excess water to flow on down the sewer. This spring folding mechanism is so designed for a scooter up to 12 inches that a single control line can be used.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 354.

6.24F What must be done *BEFORE* equipment is set up in the street?

6.24G What is the purpose of the manhole jack or control cable guide?

6.24H During set up, how can the level of water in the manhole and sewer above the scooter be controlled?

6.243 Cleaning Operation

Let the scooter go downstream a few feet and test the folding mechanism of the head shield (Maintenance Equipment Operator). Give the control line a short, smooth pull back two or three feet and hold. If the build up of water in the manhole starts to go down, you will know the folding mechanism is working properly. If the folding mechanism does not work properly, pull scooter back out of manhole and look for cause of problem by inspecting shield release mechanism for proper operation.

When the scooter is working properly, continue the operation by allowing slack in the control line. The slack will permit the shield to return to the upright position and the water pressure will increase behind the scooter. Allow the scooter to work its way downstream, keeping a tension on the control line. A continuous flow of water and a steady tension on the control line will insure a smooth cleaning operation.

Attention must be given to the amount of head or water in the manhole above the invert, the best cleaning action results when the depth of water in the manhole is three times the pipe diameter. For an 8-inch line, on a flat grade, 24 inches of water above the invert of the manhole will provide sufficient head for cleaning and not flood most homes without basements. Higher wastewater levels in the working manhole increases the scooter cleaning efficiency, but causes a greater risk of flooding. The cleaning efficiency of the scooter is increased as pipe size increases. This is due to the increase of head pressure and the water scouring jet action between the head shield rim and the pipe walls.

This high turbulence will force the debris to move downstream ahead of the scooter. If the flow in the collection system is not sufficient for effective cleaning, you will have to add more water to the upstream manhole by using water from the tank truck or from a fire hydrant.

If the scooter slows or stops during the operation, it is probably due to an accumulation of material ahead of it. This problem also may be indicated by a sudden rise of the water in the working manhole. When material builds up ahead of a scooter, give the control line a short, smooth pull back four or five feet. This will allow the upper half of the head shield to fold back and a surge of water to flush the accumulated material on downstream.

Continue repeating this operation until the level of water in the working manhole stays fairly constant, at the pre-selected level, indicating normal operation.

Continue this operation until the scooter has reached the downstream manhole.

Someone must watch the flow of material into the lower manhole to prevent a buildup of material that could flow over the debris trap (Maintenance Man I). If this occurs, loosened material is lost farther down the line and this manhole itself could become plugged. Remove the debris before the cleaning operation is allowed to continue. Debris removed requires additional help because flow control has to be maintained at the upper manhole. Notify or signal the operator of the scooter to shut off any extra water being put into the manhole and hold up the scooter's progress.

Before entering the manhole, recheck for gases found in sewers and equip the operator with a safety harness, hard hat, and gloves. The material will be scooped into a suitable debris bucket and brought to the surface with a hand line. Help *MUST* be topside during this operation.

Set up for scooters, sizes 15 inches and up, differs from smaller scooter sizes because a second control line is used to trip the head shield and powered drum equipment is used instead of the hand line method.

If a bucket machine or balling machine winch is used to guide the scooter down the line, they will be equipped with steel cables. A ⅜-inch cable will be large enough to control the scooter and ¼-inch cable for the control of the head shield. Half inch cables are used for lines larger than 18 inches.

The cable guides would differ in that two cables instead of one will be working in the line and they both should run over a roller to prevent damage to the cable.

The powered equipment usually is set up over the working manhole with the control cables running straight down into the manhole.

The bucket machine or balling machine winch, usually trailer mounted, has stabilizer legs which give a firm installation.

Trapping of material at the lower manhole also will differ on larger lines. The standard elbow style debris trap will do an excellent job on lines up to 15 inches. In larger lines the amount of flow has to be considered. Usually all but large objects will break up and be carried with the flow. To trap these larger objects, a grill type device or bar screen can be used which will allow the flowing of water to pass through the manhole.

When the cleaning operation is completed, the scooter is removed at the lower manhole and the control cables wound back on their respective drums.

The lower manhole should be cleaned of debris and the trapping equipment removed.

The material removed should be loaded for disposal and the street area cleaned as needed.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 354.

6.24I How can you determine if the folding mechanism is working properly when the scooter starts downstream?

6.24J What is the recommended depth of water in a manhole during a scooter cleaning operation?

6.24K What must be done if flow in the collection system is not sufficient for effective cleaning?

6.24L What could cause a scooter to slow or stop during the cleaning operation?

6.24M When material builds up in the line and slows or stops the scooter, what can be done to correct the problem?

6.24N Why should someone watch the flow in the downstream manhole during the cleaning operation?

6.24O What must be done *BEFORE* debris can be removed from a manhole?

6.244 Precautions and Safety

As with all cleaning methods, certain precautions need to be taken before and during the operation.

One of the most important precautions for this method of cleaning is to determine if a build up of water (head of water in the working manhole and in the sewer being cleaned) will flood a residence or business. The scooter requires a good head pressure to function effectively.

Examine the manhole structures on large lines to be sure the sewer scooter can be installed.

More time is needed to set up and remove the larger units. Allow for this time when preparing work schedules.

Always examine cables at start and finish of each section to avoid having a cable break when the scooter is in the middle of a sewer.

6.245 Records

See Section 6.18, Records.

6.25 Kites, Bags and Poly Pigs

Kites (Figure 6.20), bags (Figure 6.20) and poly pigs (Figure 6.21) describe equipment commonly used to clean larger diameter sewers. For example, instead of using a sewer ball to clean a large diameter sewer, use a kite or bag slightly smaller in diameter (2 inches smaller) than the sewer. With a small head (2 feet) on the sewer, the velocity of water flowing around the outside of the bag or through the outlet of the kite will create a cleansing velocity like the velocity around a sewer ball. Kites are called parachutes too.

The procedures and precautions for using either kites or bags are similar to those for balling in Section 6.21. Poly pigs are used in force mains similar to balling, but a cable is usually not attached to the poly pig. Poly pigs may be equipped with a small radio transmitter for tracking the pig's travel through the sewer line and fittings.

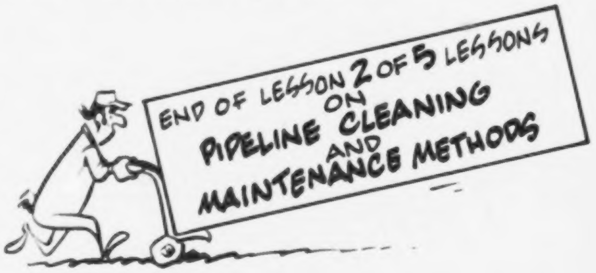
QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 354.

6.24P Why should the cables be examined at the start and finish of each section?

6.25A Instead of using a sewer ball, how are larger diameter sewers cleaned?

6.25B How are force mains cleaned?



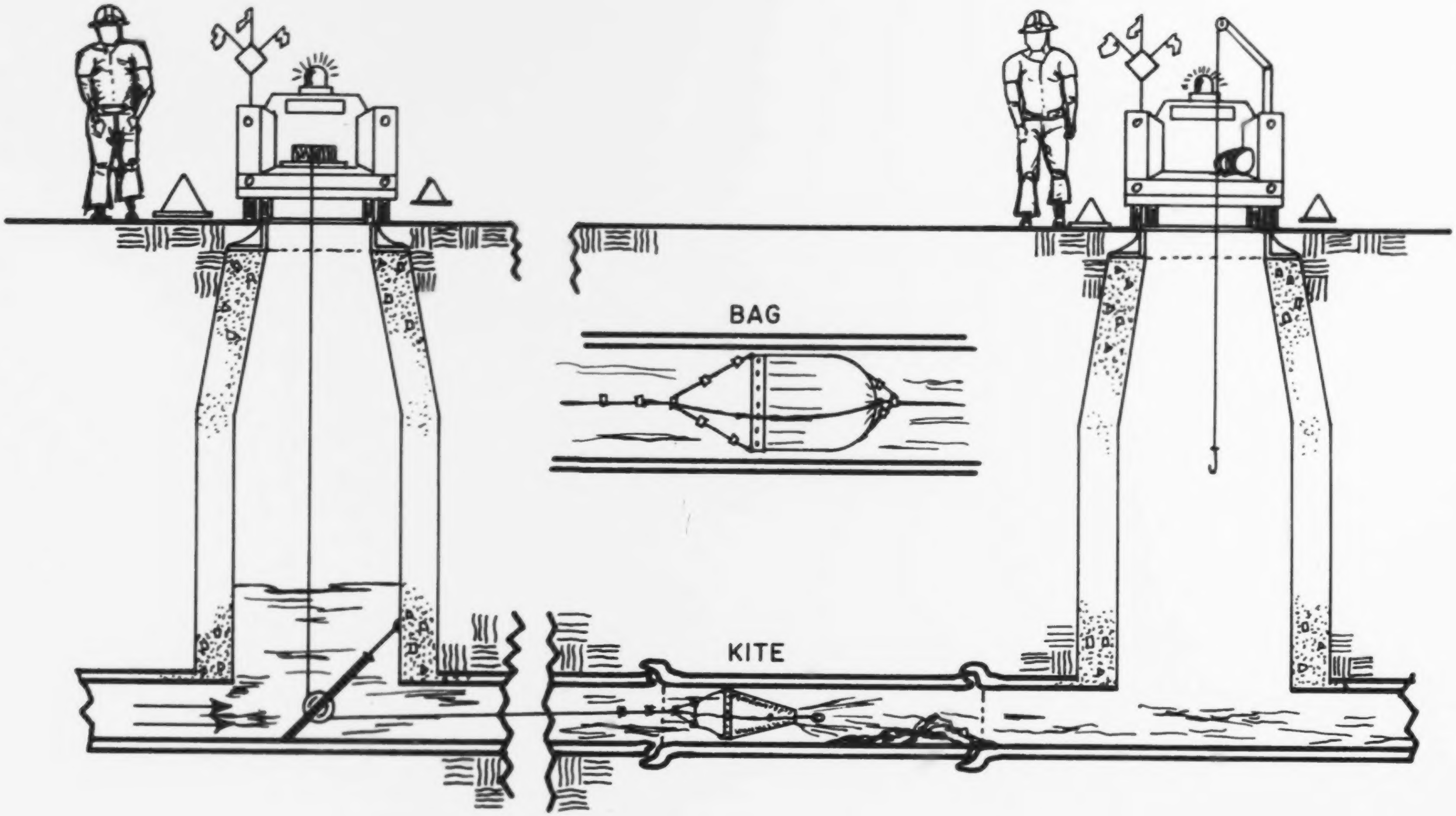
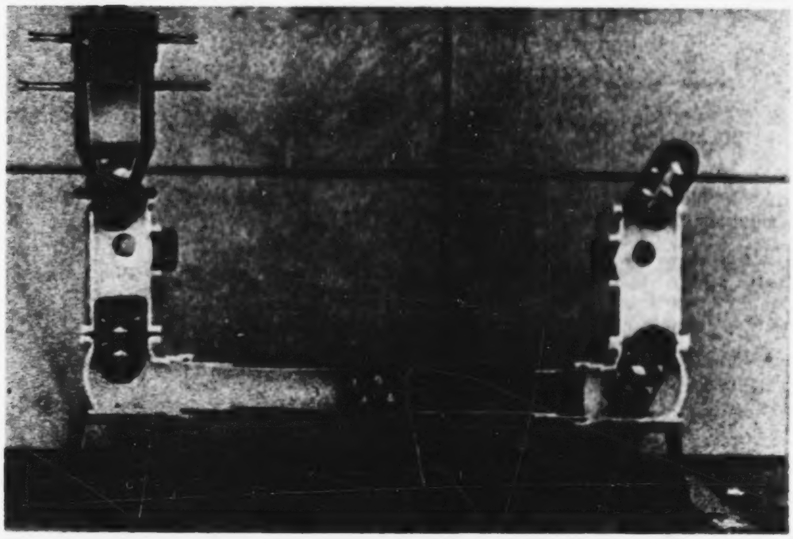
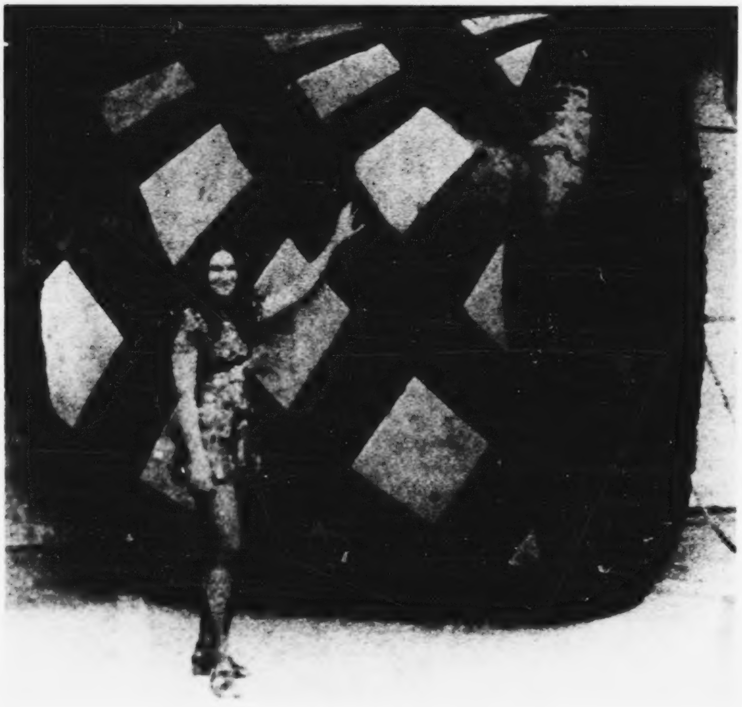


Fig. 6.20 Kite or bag cleaning operation



Use of poly pig in force main



Nine-foot diameter poly pig
Typical sizes range from 4 inch to 60 inch

Fig. 6.21 Poly pig
(Courtesy of Girard Polly-Pig, Inc.)

DISCUSSION AND REVIEW QUESTIONS

Chapter 6. PIPELINE CLEANING AND MAINTENANCE METHODS

(Lesson 2 of 5 Lessons)

Write the answers to these questions in your notebook before continuing. The question numbering continues from Lesson 1.

7. How do hydraulic cleaning methods clean sewers?
8. What precautions have to be taken during all hydraulic cleaning operations?
9. What would you do if a sewer ball became stuck in the middle of a sewer during a balling operation?
10. Why do sewer cleaning crews often use hand signals?
11. How fast and how far into the sewer should the nozzle of a high velocity cleaner be allowed to go?
12. How effective is flushing?
13. What types of conditions are best suited for the use of a sewer scooter?

CHAPTER 6. PIPELINE CLEANING AND MAINTENANCE METHODS

(Lesson 3 of 5 Lessons)

6.3 MECHANICAL CLEANING

Wastewater collection line cleaning techniques described in this section rely on a mechanical action to clear the sewer. This clearing action results from the material in the sewer being removed by a scraping, cutting, pulling, or pushing action caused by a mechanical device or machine. Clearing techniques outlined in this section include bucket machines, power rodders and hand rods.

6.31 Power Bucket Machines

6.311 Use of Power Bucket Machines

Sewers are purposely designed to develop sufficient velocity to provide a self-cleaning action and to convey solids through the system to the wastewater treatment plant. When deposition of solids occurs in a sewer, first consideration should be given to hydraulic cleaning techniques to remove the solids from the sewer. Hydraulic cleaning techniques include balling the line (Section 6.21) and using a high velocity water jet (Section 6.22). These techniques are used due to their simplicity, effectiveness, and the costs of removing the deposited solids when compared with other sewer cleaning techniques. Hard grease and soap may be removed by using a porcupine followed by a cleaning tool with a swab (Figure 6.22).

There are instances when the hydraulic techniques are not the best method of removing roots or deposits of solids because of the volume, size, weight, or type of material that may be found in the sewer.

This material may be lumped together or spread separately along the line. Types of deposits include silt, sand, gravel, or some type of industrial solid waste. The entry of silt, sand,

Pull-type swab used to follow the cleaning of a line with a porcupine

Fig. 6.22 Porcupine and swab
(Courtesy of Union Sanitary District)

gravel, and rocks into the collection system is often traced to some damage either to the sewer line or manholes, or a section where repairs were made to the system. Pipes or manholes may be broken by various construction projects, grade changes of streets, earthquakes, or excessive loads from vehicles and heavy equipment. When a pipe breaks, large quantities of debris can enter the collection system.

When there is an indication that a sewer is failing, and that sand or mud is entering the sewer, do not use a high velocity cleaner. Nozzle action develops a negative pressure that can hasten the collapse of a bad section of pipe. A bucket machine can be used to remove the sand or mud when proper care is exercised. If possible, televise the sewer as soon as possible to determine the cause of the problem and the condition of the pipe.

To clean a line after a pipe breaks, the power bucket machine can be used effectively both before and after repair to remove the heavy deposited material. Next clean the sewer hydraulically to restore it to full capacity. A damaged line must be repaired to prevent the entry of more material.

The power bucket machine is a necessary maintenance tool, but it should be used only when absolutely necessary. They are heavy and the operation is a slow process. Power bucket machines are used mainly to remove debris from a break or other debris that can't be removed by hydraulic cleaning techniques. Also they can be used as scrapers with a root cutter or porcupine. They should not be used as a routine cleaning tool on a regular basis. Broken lines must be repaired and kept tight so the bucket machine won't have to remove debris from the same broken pipe location again.

Figures 6.23 through 6.28 show power bucket machines, accessories and the equipment set up.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 354.

6.31A Identify two sewer line mechanical clearing techniques.

6.31B What clearing techniques should be given first consideration when solids deposit in a sewer?

6.31C Under what conditions would hydraulic clearing techniques not be feasible?

6.31D When should power bucket machines be used?

6.312 Manpower and Equipment

Buckets range in size from six inches to thirty-six inches in diameter. Volumetric capacity of the buckets range from 0.13 cubic feet to 8.5 cubic feet. An 18-inch diameter bucket will pass through a standard 24-inch diameter manhole opening and has a volume of approximately 1.6 cubic feet.

The bucket machine is usually trailer-mounted (Figure 6.23), but can be truck-mounted. Trailer-mounted bucket machine units must have a pintle safet hook attached to the truck that tows the trailer to the job site. Also a wire cable and shackles should be placed around the truck frame and to the frame on the bucket machine for added safety in case the pintle hook fails.

The bucket machine units have a steel framework on which is mounted a gas engine and a drum winch. The drum is coupled to the engine through a controllable drive train, usually a chain and belt drive combination. The drum is capable of holding 1,000 feet of ½-inch steel cable and is mounted on the framework in such a position that it can be centered over a manhole. The framework includes a vertical "A" frame of sufficient height to allow the cleaning bucket to be lifted above ground level.

Two machines are needed for this operation and both are basically the same in design. At least one machine also will be equipped with an additional smaller drum capable of holding 1,000 feet of ¼-inch steel cable. This drum can be operated separately from the ½-inch cable drum. The purpose of the small cable and drum is twofold. One is for the purpose of threading the sewer line from manhole to manhole, and the other is to have a suitable cable which can be left in the line overnight. The drum is, therefore, often referred to as an overnight drum.

An optional addition to one machine may be a chute with rollers and shaker bar which allow the material removed to be dumped directly into a dump truck. Machines without this attachment have the "A" frame as previously mentioned. The machine which does the pulling of the bucket out of the manhole will be referred to as the working machine. It will have a small swinging boom or arm attached to the "A" frame which is used for dumping the full buckets. Operation of this machine will be described later in Section 6.313.

With each bucket machine, equipment will be needed in the manhole to guide the cable into the sewer line without rubbing or cutting into the pipe. At the working machine, use a V-shaped roller (Figure 6.24) of sufficient size to accommodate the size bucket being used. This roller will be held in place by means of a steel pad which in turn is firmly secured flush with the street surface by two adjustable stabilizer legs on the machine. The companion machine may use the same method or perhaps use a slant jack (Figure 6.24) in the bottom of the manhole for the cable to travel over. This would dispense with the use of the pad and roller.

A variety of tools are available for use with these machines and more are being developed, making these machines usable for purposes other than bucketing of debris. Root cutters and insertion pullers can be used with bucket machine power winches.

For this discussion, we will consider the use of the clamshell bucket (Figure 6.23) and porcupine tool. These are available in sizes from 6 to 36 inches in diameter, but sizes under 12 inches are rarely used.

The bucket is of such design that when being pulled into the sewer line the jaws are in an open position. The jaws dig into the deposits of material.

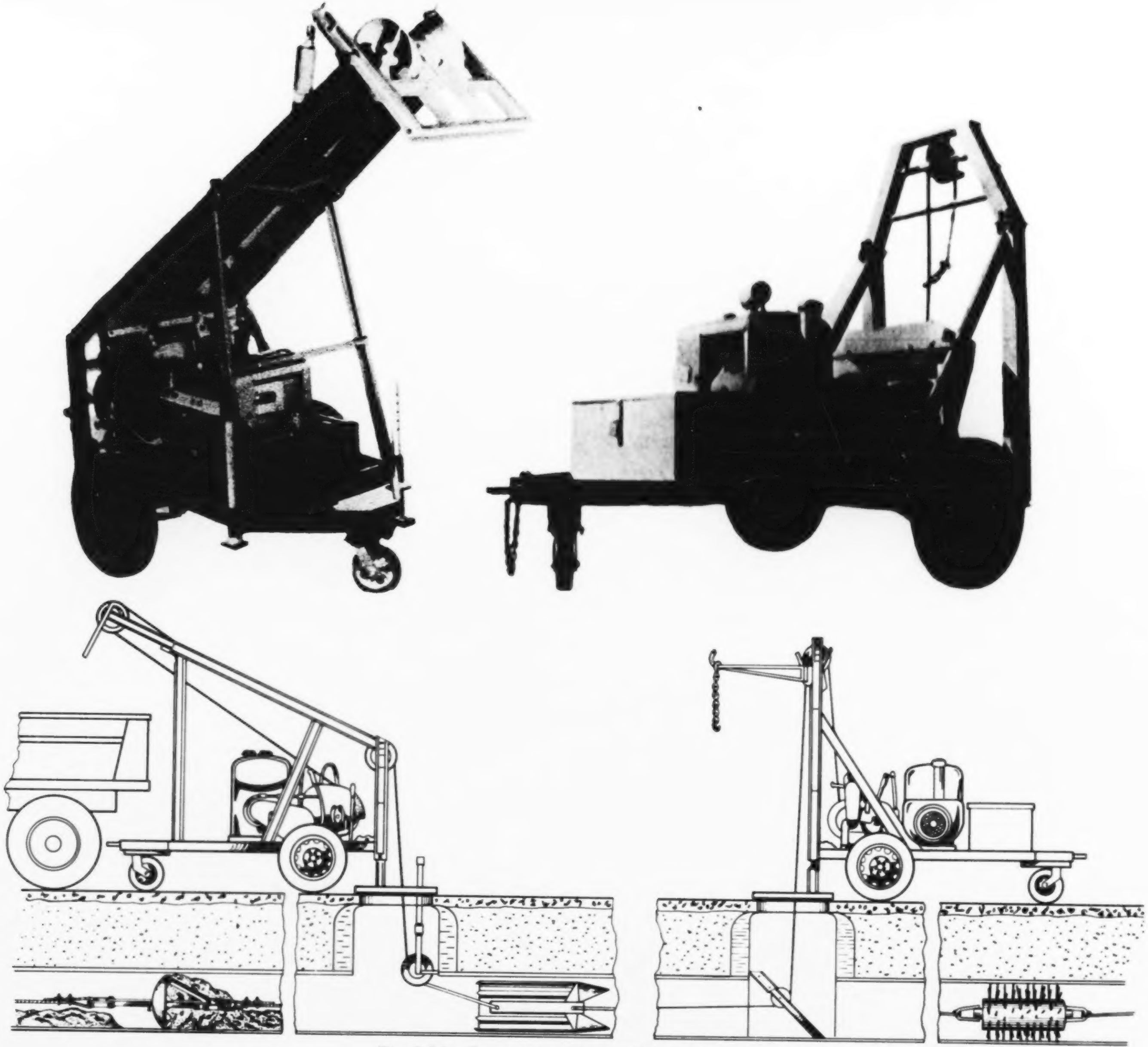


Fig. 6.23 Power bucket machines and set up

(Permission of Sewer Rodding Equipment Company)

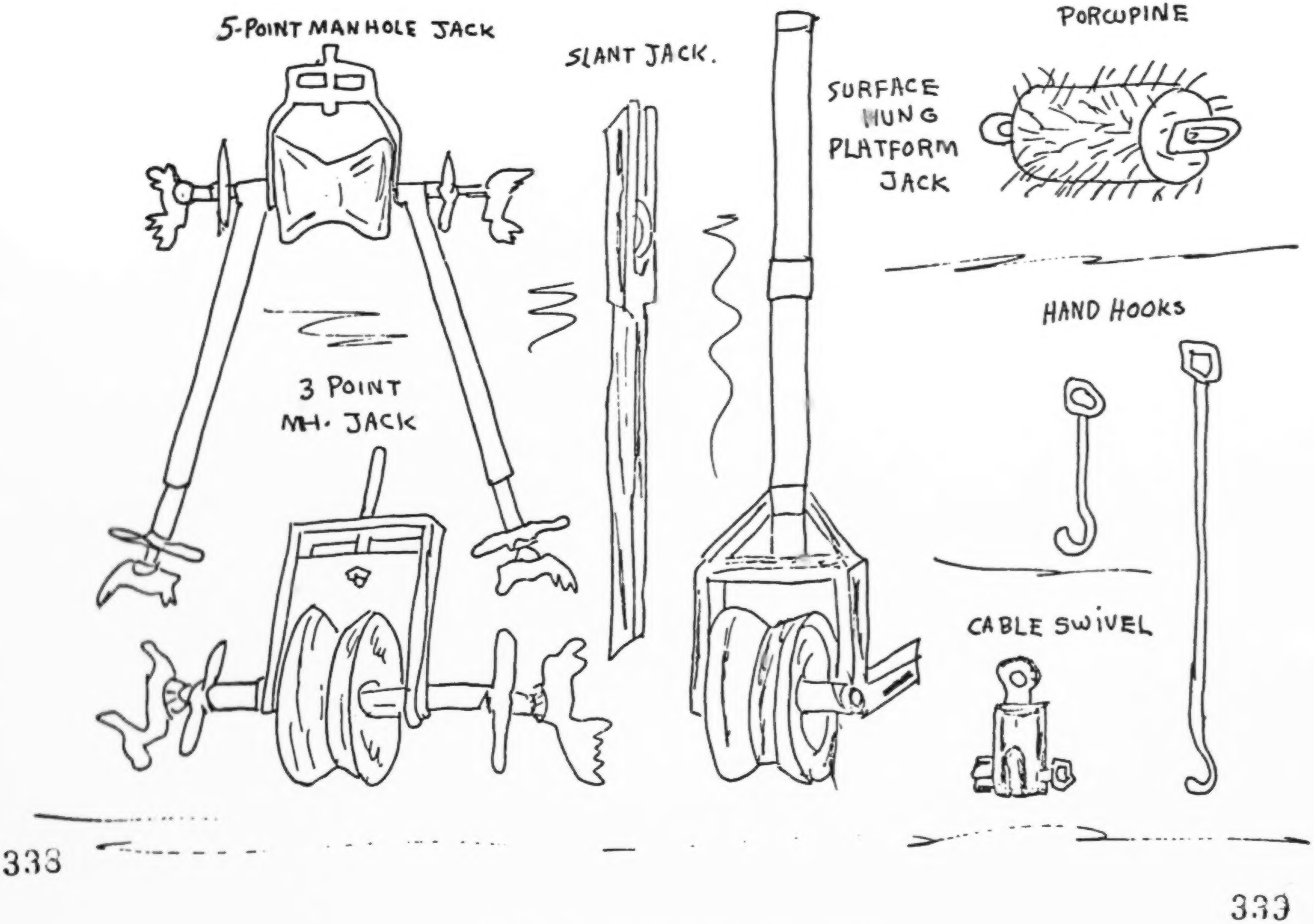

5-POINT MANHOLE JACK
SLANT JACK.
SURFACE HUNG PLATFORM JACK
PORCUPINE
HAND HOOKS
3 POINT MH. JACK
CABLE SWIVEL
338
339

Fig. 6.24 Power bucket machines and accessories

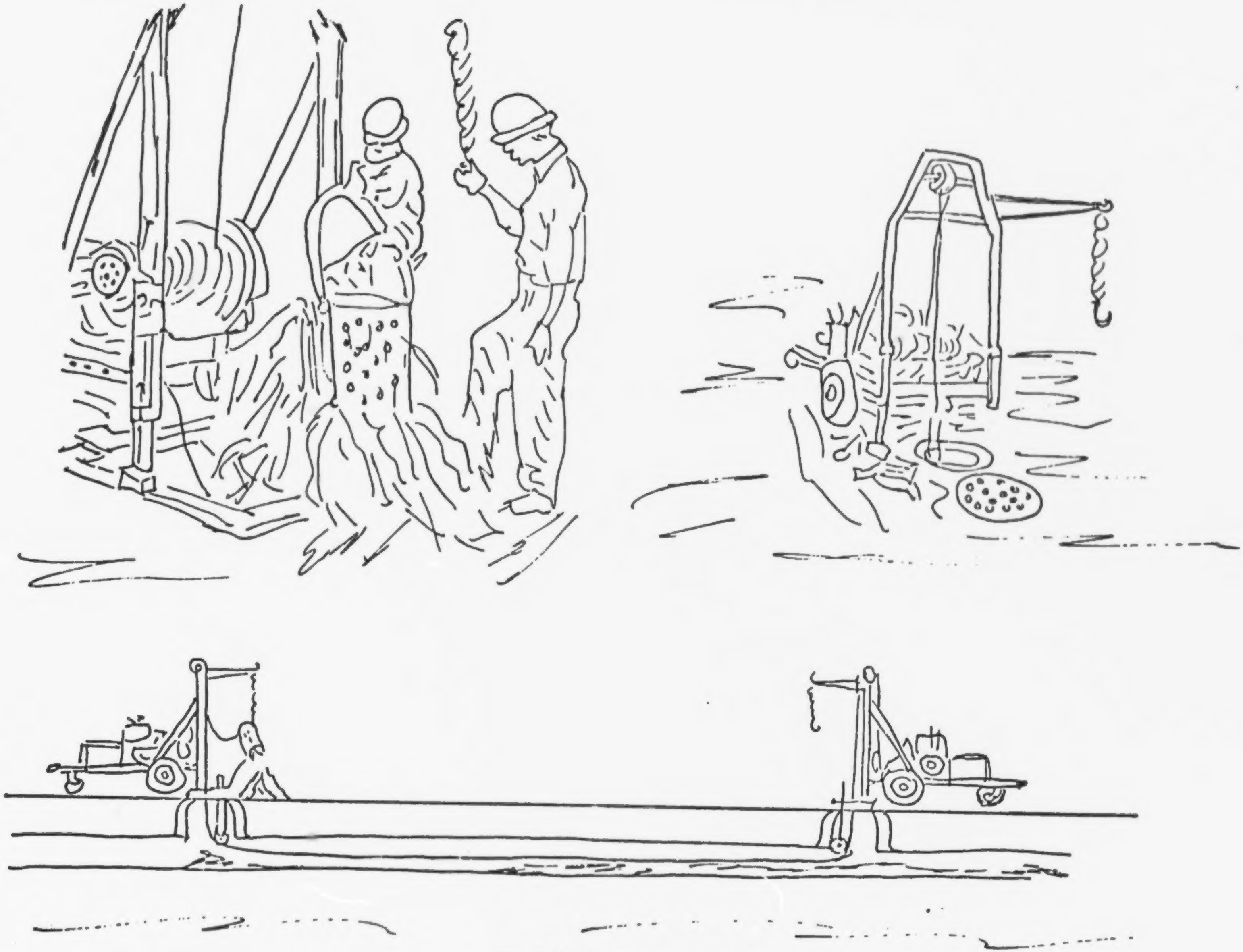
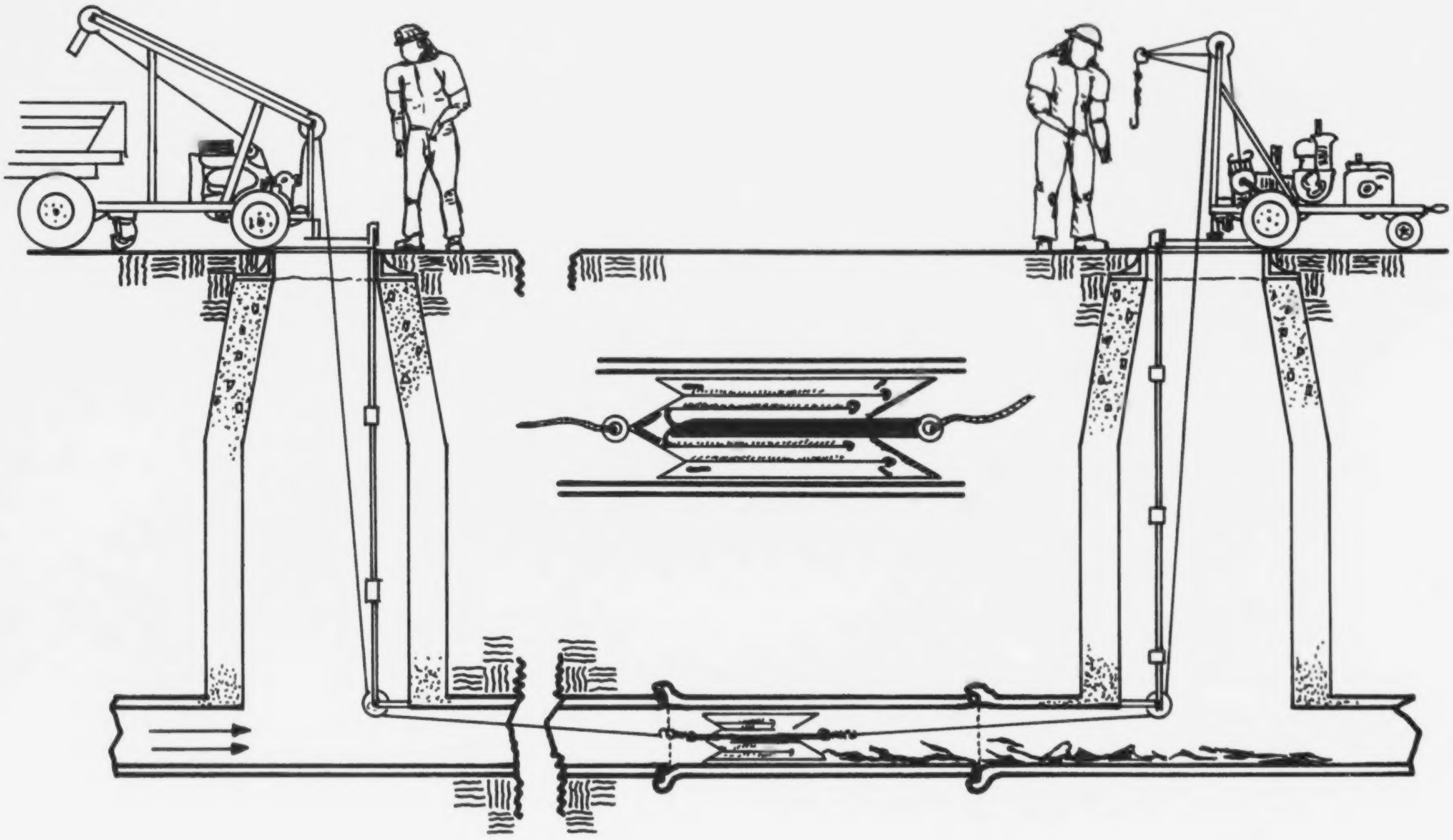


Fig. 6.25 Power bucket machines

NOTE: Working machine is at the upstream manhole.

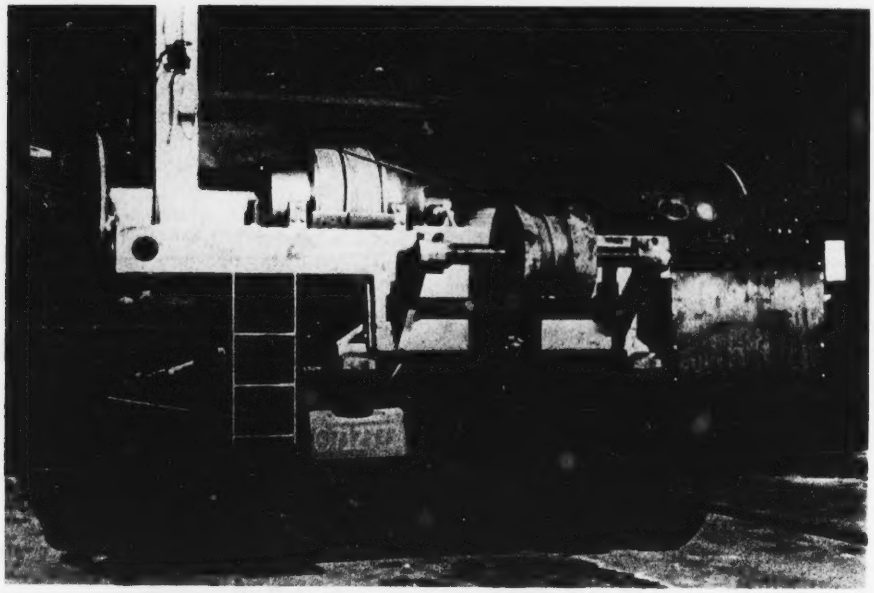


NOTE: Working machine is at the upstream manhole.

Fig. 6.26 Power bucket operation

Pull-type swab with holes in discs for flushing action. Used for cleaning lines with grease and as a follow-up cleaning after a swab (Figure 6.22).

Fig. 6.27 Swab with holes in discs
(Courtesy of Union Sanitary District)



Heavy-duty hydraulic winch truck used when cleaning larger lines

Fig. 6.28 Winch truck
(Courtesy of Union Sanitary District)

When the working machine pulls the bucket out, the jaws are forced closed by means of a slide action. Any material in or in front of the bucket is scooped up.

The porcupine tool is a steel cylinder having solid ends with eyes cast in them to which a cable can be attached. Many short pieces of cable protrude from this cylinder like a round brush. This tool is quite effective for final cleanup since the bristles have a scrubbing action.

Equipment needed other than that furnished with the bucket machines includes sandtraps, manhole shovel, debris bucket and hand line, manhole lifter, pipe wrenches, and hand tools such as crescent wrenches and pliers.

Safety equipment includes flags, cones, barricades, traffic signs, sewer gas detection equipment, safety harness and rope, and such other safety devices the job setup may require (see Section 4.3, Routing Traffic and Section 4.4, Manhole Hazards).

Experience has shown that many unexpected repairs occur during the clearing operation. Extra cable swivels, clevises, cable clamps, and other essential accessories should be readily available if not with the machines.

The number of operators needed to effectively conduct the clearing operation will vary, but at least three operators are needed and four operators are recommended. If traffic control dictates, flagmen will also be needed. Manpower requirements:

1. Maintenance Equipment Operator,
2. Maintenance Man I,
3. Maintenance Man I, and
4. Maintenance Man II.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 354.

6.31E What is the purpose of the working machine?

6.31F What is the purpose of the porcupine tool?

6.31G How many operators are needed on a power bucket crew?

6.313 Equipment Set Up

Whether the working machine is set up at the upstream or downstream manhole depends on field conditions. In smaller sewers with lower flows the working machine is usually located at the downstream manhole. Under these circumstances there is little tendency for the material being removed to be washed out of the bucket. Also working from the downstream manhole reduces the possibility of a stoppage developing in the sewer below the working area.

Often the working machine is located at the upstream manhole (Figure 6.26) when clearing debris from larger sewers. Under these conditions the debris in the full bucket tends to remain in the bucket because the bucket is being pulled against the flowing water when the full bucket is returned to the working manhole. If flows are low, the possibility exists of a stoppage developing downstream from the working area.

Once this equipment is set up, it usually remains in one position for several hours. Special emphasis is placed on safety measures taken for control of traffic and insuring a safe environment in a manhole (see Section 4.3, Routing Traffic, and Section 4.4, Manhole Hazards).

TRAFFIC ROUTING
HI! PLEASE TURN BACK AND REVIEW SECTION 4.3 ON PAGE 116

MANHOLE HAZARDS
HI! PLEASE TURN BACK AND REVIEW SECTION 4.4 ON PAGE 124

Bucket machine clearing requires a certain amount of skill in operation of the equipment and this can be obtained only by actually working with the equipment. This method is one of the more expensive operations due to several factors, but mainly the hours involved in setting up the equipment. In the process of bucket machine clearing, it is not unusual to find you cannot complete the job before the end of the day. Because of the time and effort needed to thread the line, the overnight line is left in the sewer. This will be discussed further in Section 6.314, Operation.

During the set up operation, communication has to be established with both the operators at the upstream and downstream manholes. Communication may be either by sound powered telephones, radio, or signals as shown in Section 6.21. A fool-proof system must be devised and used between winch operators because someone can easily be injured if the proper signal is not sent, received, or is misunderstood.

The two machines are positioned over the respective manholes (Figure 6.26); the working machine at the downstream manhole and the backpull machine at the upstream manhole. The pads are placed under the stabilizer feet of the machine and these feet jacked down so sufficient weight of the machine holds the pad in place. The legs also function as a method of leveling the bucket machine. Insert a sand trap or debris trap in the downstream line to stop material pushed ahead of the bucket when clearing.

The lower manhole roller is lowered into the manhole by attaching various lengths of threaded pipe, usually 2-inch pipe in 4-foot sections. With this roller properly situated, the cable and bucket must clear the top of the sewer, the pipe is then secured to the pad by means of a chain clamp device. With this firmly in place, the roller will not lift up when strain is applied to the cable while pulling. Give consideration to this NOW since there is the same pressure exerted to lift up on the roller in relation to the power exerted in pulling with the cable. If there is a set up problem, roller security is one of *THE FIRST* problems encountered when the clearing operation starts.

As described previously, the upstream machine may possibly be set up with a slant jack type roller (Figure 6.24). If so, the pad and roller, with pipe extensions, will not be needed. Again, make sure the slant jack is secure since this machine will be exerting considerable lift-pulling action also.

To thread the sewer, a synthetic rope can be used. The upstream machine can be equipped with a small drum exactly the same as the "overnight" drum on the downstream working machine. One thousand feet of the synthetic rope can be carried on this drum. Some synthetic rope has been known to deteriorate without warning due to chemicals in wastewater.

To this rope attach a nylon parachute designed and available for such use and allow this parachute to float downstream to the working manhole. A high velocity cleaner may be used to string the line also. Attach the parachute rope to the ¼-inch steel cable of that machine. A swivel must be used to keep the rope and cable from twisting. The upstream operator engages the small rope drum and pulls the ¼-inch cable upstream to the machine. Remove the rope drum from the machine so it will not interfere with the operation. Connect the ¼-inch cable and swivel to the ½-inch cable. When ready, signal the downstream operator to engage the small drum of the machine and pull in the ¼-inch cable, thus threading the sewer line with the ½-inch cable. The operator of the working machine will likewise remove the ¼-inch cable drum.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 355.

6.31H Why might an overnight line be left in the sewer?

6.31I Why must a fool-proof communication system be devised and used?

6.31J What is the purpose of the swivel between the parachute rope and the ¼-inch steel cable?

6.314 Operation

The clearing bucket is now ready to be attached to the cable. Experience and history of the sewer line dictates how much smaller a bucket must be than the actual diameter of the sewer. A cable swivel of sufficient size is attached to each *BAIL OF THE BUCKET*[5] by means of a clevis. The ½-inch cables are then attached to the swivels using a clevis. Position the bucket so the jaws will be opening upstream.

Take up the slack in the cable of the working machine (Maintenance Equipment Operator) until the bucket is hanging free over the manhole. Signal the upstream operator (Maintenance Man I) to take in the cable. Hold the brake securely on the working machine to keep the bucket from dropping into the manhole. Experience is gained quickly at this point because special care has to be taken in getting the bucket around the lower roller and into the sewer.

At the start, always make a few short pulls to check out not only the amount of material in the sewers, but also the equipment and the set up. One approach is to try an undersized bucket first to determine if it can be pulled through the sewer. If this works, a larger bucket can be tried because it will remove more material before it is full. As the bucket is pulled upstream into the material deposited in the sewer, a definite resistance can be noticed when the bucket is full.

When the bucket is full, pull the loaded bucket back out of the sewer. To start pulling the bucket back, signal the working machine operator after disengaging the machine. Hold a slight amount of brake to keep the cable from spooling too freely as the bucket is pulled downstream. If the working machine is equipped with a footage counter, watch closely as the full bucket nears the manhole. Reduce the speed of pull when the bucket enters the manhole and makes the sudden turn around the lower roller and up to the street surface. If a footage counter is not used, the operator can quickly note the cable wraps and their position on the drum. This technique also can apply when the bucket is being pulled upstream. The operators, by knowing the approximate diameter of the drum, and the number of wraps or layers pulled off, can judge fairly closely the distance the bucket is in the sewer. Bucket location is important to this operation.

When the bucket is pulled back out of the manhole and a sufficient distance above street level, the helper will swing the small boom out and attach a hook and short chain to a special eye on one side of the open end of the bucket. With a long hook, this helper will quickly pull the bucket to one side and away from the manhole by engaging the hook on the lower bale of the bucket.

At the same time, the machine operator releases the brake, thus allowing the bucket to drop. When the bucket is suddenly stopped in mid-air by the short chain on the boom, the jaws slide open and allow the debris to spill on the street or into a container or truck. Practice and coordination of this operation between the operator and the helper will result in keeping the pile of debris in one area where it can be loaded and hauled away.

The operator will engage the cable drum, again lifting the bucket enough so the short chain can be unhooked from the bucket. The operation is now ready to be repeated. After several pulls, check the build-up of material against the sand trap in the bottom of the manhole. This material should be removed before it is lost downstream.

When the bucket of the correct size has been pulled freely from the upstream manhole to the lower manhole, it may be advisable to finish cleaning the sewer with the porcupine cleaning tool. Remove the bucket, fasten the two cables together and pull the cable upstream until the swivels are above street level. Attach the porcupine with a swivel at each end and insert it carefully into the sewer. If a slant jack is used, the porcupine may have to be put on in the manhole due to the design of most slant jacks. If a pad and roller are being used, allow the working operator to slowly pull the porcupine into the sewer and then on downstream where it can be removed.

---

[5] *Bucket bail. The pulling handle on a bucket machine.*

WARNING

DO NOT PULL THE PORCUPINE UPSTREAM SINCE IT HAS A TENDENCY TO SEAL OFF THE LINE AND CAUSE THE SEWER TO BACK UP.

This in turn may cause problems of flooding if there are building laterals connected into the sewer being cleaned.

Since each machine is capable of handling 1,000 feet of cable, often it is possible to pull through or skip a manhole, thus saving another time-consuming set up. Two sections can be cleared at once, provided the sections are in a straight line. A disadvantage of this procedure is that you may greatly increase pipe damage by more trips through the same section of sewer. A short damaged section may become a long damaged section.

If the working machine is equipped with a truck loading chute, the operation of dumping the bucket is done by the machine operator. Loading chutes eliminate loading the material from the street to the truck and considerable clean up. An extra operator is important at this end of the operation even with the chute method of dumping. Often the operator needs help when the controls of the machine cannot be left. When extra help is not available, the danger of accidents is greatly increased. This method of clearing is time consuming; and when the operation is hurried, quality of clearing, equipment care, and safety are often unintentionally sacrificed.

If the job is not complete at the end of the day, the bucket is removed at the downstream working manhole, and the ¼-inch overnight drum is installed and connected with a swivel to the ½-inch cable of the upstream machine. When the ¼-inch cable is pulled through, it is secured in the upstream manhole in such manner that it cannot come loose. The manhole cover can be replaced.

The ¼-inch cable and drum are then removed from the downstream working machine and lowered into the manhole and secured.

The pull line will be ready for the next day's set up and considerable time saved.

When work is complete, the reverse procedure of set up is used to remove the equipment from the sewer and the manholes. Hose off buckets and cables. Load the equipment into the trucks and prepare for the next set up or the next day's use.

Final clean up is performed with special care given to washing down and completely cleaning the entire area where debris or wastewater has been deposited on the street surface during the operation..

In these instructions, the set up of this equipment has been to have the working machine at the downstream manhole and to do the actual clearing by going upstream into the material to be removed. This does not mean the reverse procedure cannot be used and it often is. However, conditions in the sewer must be kept in mind and particularly the results of whichever procedure selected. If large amounts of debris and especially roots are encountered when pulling the clearing tool downstream, a stoppage can be caused below the working area. By working upstream as outlined, this danger is practically eliminated. However, use of improper tools and techniques also can allow debris to cause a stoppage downstream. Again, the continuous use of this equipment and the experience gained will govern the choice of the set up procedure.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 355.

6.31K What size clearing bucket should be selected?

6.31L How can you tell when the bucket is full?

6.31M Where is the debris in the bucket first dumped after the bucket is removed from the manhole?

6.31N Why is a sand trap inserted in the downstream manhole?

6.31O How can the sewer line be cleaned after a bucket has been pulled through the line?

6.31P Should the porcupine be pulled upstream or downstream?

6.31Q Why should the bucket be pulled upstream?

6.315 Precautions and Safety

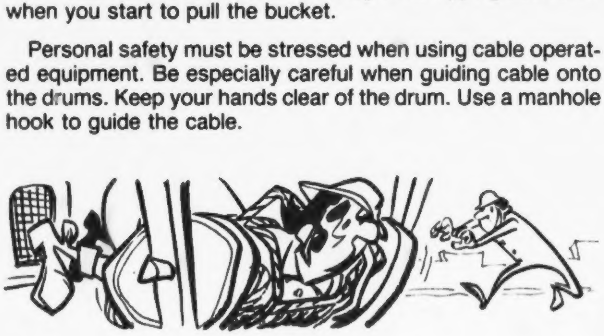
Because a rather large tool is being used in the sewer, any problem encountered which would keep the bucket, porcupine, or other such clearing device from moving can cause water to build up behind it. Prevention of stoppages during clearing should be foremost in the mind of the operator. If there is any question of the clearing tool getting through, try a smaller size and determine if the sewer would allow a larger tool to pass through the sewer. As mentioned previously, it is important to know the location of the clearing tool at all times. Footage counters are recommended; but if they are not available, keep track of the wrap of cable. In the event the clearing tool has to be dug up, it helps to know where it is stuck.

Regularly inspect cable clamps, clevis and swivels, bucket condition, cable condition, and condition of accessories. If a cable should come loose from the bucket on the wrong end for any reason, you may not be able to pull the bucket through the debris to the manhole at the other end.

If a bucket becomes lodged, don't try to force your way through. If pulling the bucket upstream, have the downstream machine pull it back a few feet and try again. Pulling back will open the jaws and likely let the bucket come into the problem area at a different angle. If repeated attempts fail, have the bucket pulled back a few feet, enough to open the jaws, and then hold the brake tightly on the upstream machine while the working machine again pulls. This tends to hold the jaws open and also gives a lifting effect to the bucket.

Be careful when lowering the bucket into the working manhole. Do not allow the cable to tangle or come off the lower roller by keeping the slack out of the cable. Prevent the bucket bail from folding back on the bucket when it is pulled into the sewer because there is no way of its flipping back over when you start to pull the bucket.

Personal safety must be stressed when using cable operated equipment. Be especially careful when guiding cable onto the drums. Keep your hands clear of the drum. Use a manhole hook to guide the cable.



In an instant, your hand or fingers can become entangled and the operator cannot stop the machine fast enough to avoid injury.

New or inexperienced operators should not operate this equipment without proper training and supervision. Some of the safe practices used are techniques acquired through repeated operations and observations of problems encountered during rewinding.

6.316 Records

Since bucket machine clearing is not repeated in the same line any more often than necessary, good records must be kept. Often at a given spot in the sewer line the bucket may "hang up." This could be caused by several possible factors, but if it is a severe problem, a repair at that point may be indicated. Cocked joints can turn into broken joints if the bucket is banged against them continuously and even cause the bucket to become lodged tight. Let this event become part of the permanent record. If repairs subsequently are made, this too can be noted and the next time this sewer is cleaned, the operators will have this information. Also see Section 6.18, Records.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 355.

6.31R Why must the location of the bucket in the sewer be known at all times?

6.31S Why should the condition of the equipment be inspected periodically?

6.31T What precautions should be taken when working around cable operated equipment?

6.31U Why should particular problems encountered when clearing a sewer be recorded?

6.32 Power Rodders

6.321 Uses of Power Rodders

Power rodding machies use a steel rod to push or pull various clearing tools through sewers (Figures 6.29 and 6.30). These machines are of various designs, but are equipped to store either continuous or sectional rod in a reel-type cage in lengths up to approximately 1,000 feet. This reel can be rotated to give turning action at the same time the rod is pushed out or in.

Power rodders can be used for the following purposes:

A. Routine preventive maintenance.

B. Scheduled clearing of:

  1. Grease deposits
  2. Roots
  3. Debris accumulations

C. Threading cable for:

  1. Balling equipment (15-inch diameter and larger lines)
  2. TV inspection
  3. Bucket machines

D. Emergency use for clearing stoppages.

Power rodders are one of the most widely used methods for clearing a wastewater collection system. Since the machines were introduced for commercial use in the early 1950's, many improvements have been made in design, operation, and clearing tools.

Although other clearing methods play an important role in maintaining the collection system, the power rodder can handle stubborn stoppages of roots, grease, and debris. The power rodder is called for when emergency crews cannot clear a stoppage with hand rods. This could be due to the type or size of stoppages or a distance too great for hand rods to be effective. The power rodder is a handy tool as support equipment to thread cables in lines for other cleaning and maintenance methods. After a sewer has been cleared with a power rodder, it should be cleaned hydraulically to restore the line to full capacity.

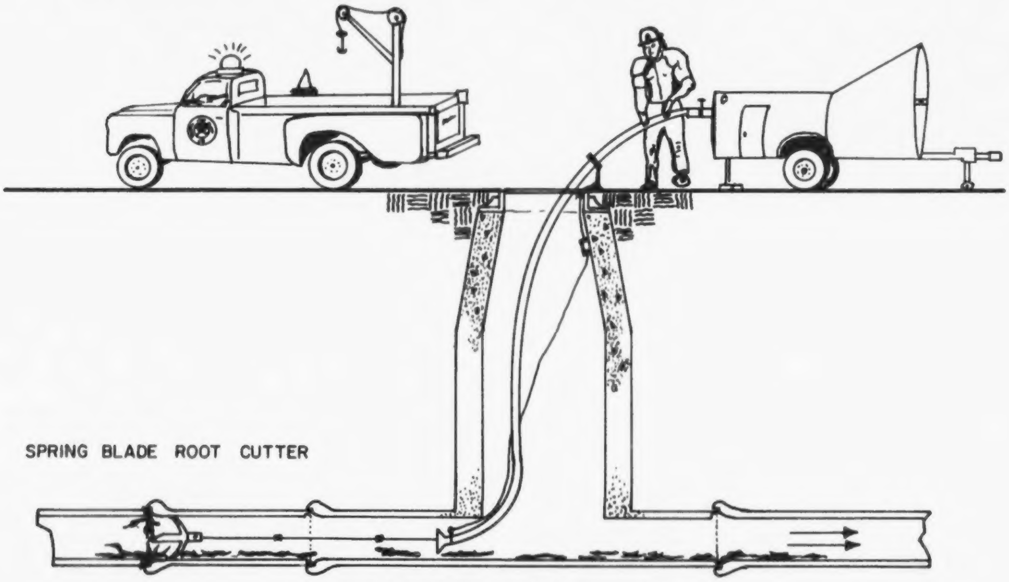


Fig. 6.29 Power rodder operation

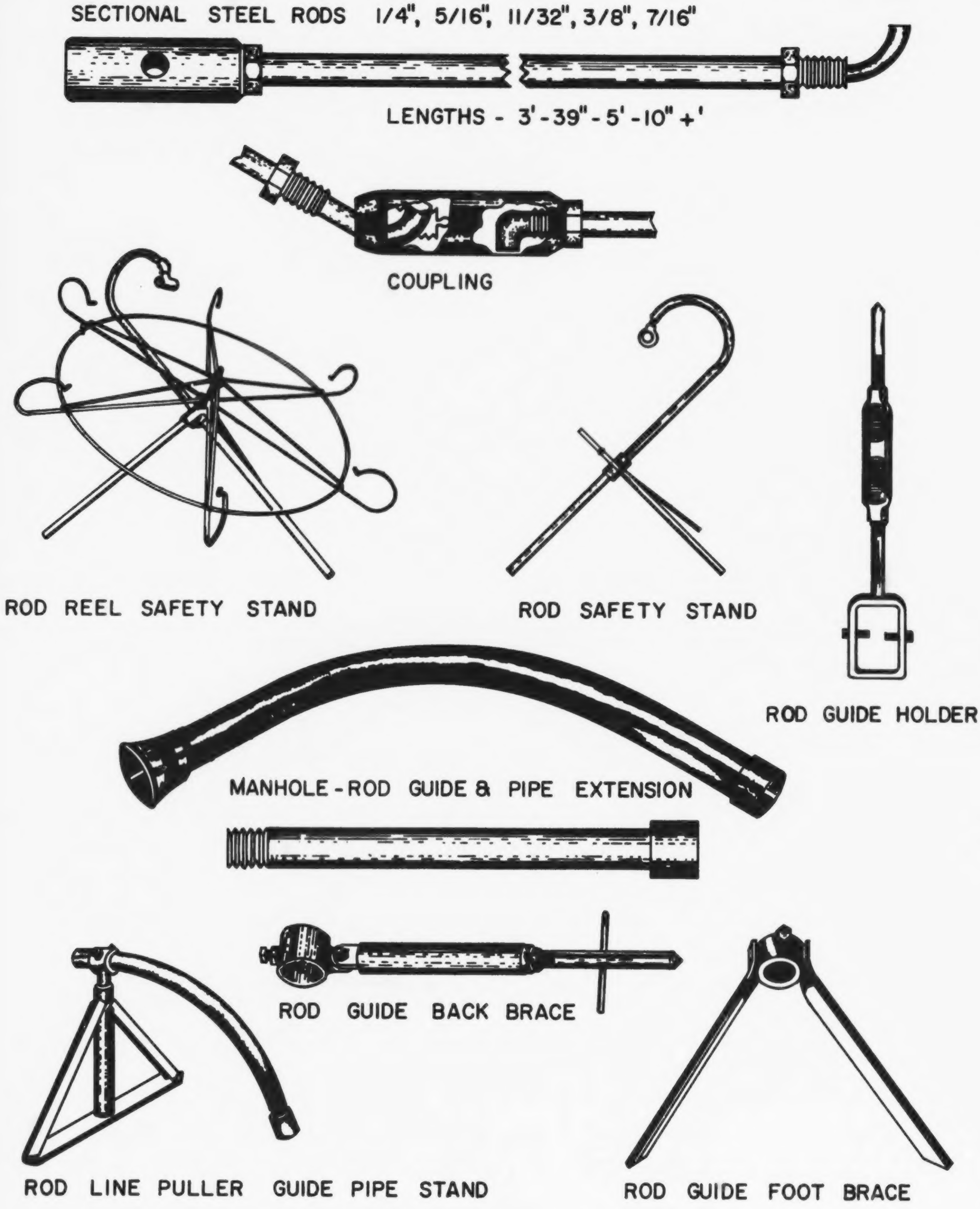

SECTIONAL STEEL RODS 1/4", 5/16", 11/32", 3/8", 7/16"
LENGTHS - 3'-39"-5'-10"+'
COUPLING
ROD REEL SAFETY STAND
ROD SAFETY STAND
ROD GUIDE HOLDER
MANHOLE-ROD GUIDE & PIPE EXTENSION
ROD GUIDE BACK BRACE
ROD LINE PULLER GUIDE PIPE STAND
ROD GUIDE FOOT BRACE

Fig. 6.30 Power drive and hand rodding accessories

6.322 Classification

The power rodder can be classified according to several different characteristics. Basically, consideration is given for either sectional or continuous type machines. There are, however, machines which employ the use of coiled rod and are called coil rodders. These are powered by either an electric motor or gas engine. The electric unit is usually equipped with ½-inch coiled rod and is capable of clearing pipe sizes to 8-inches in diameter and distances of as much as 250 feet. The gas powered coil rodder is capable of clearing line sizes of 10 inches and distances of 500 feet. A one-inch coiled rod is used on these units.

The coil rod for either of these machines is available in 25 and 50-foot sections with a thread and nut coupling.

Both machines are usually trailer mounted with the trailer equipped with storage boxes for tools and other equipment.

The clearing tools used on the coil rodders, though basically designed the same as those used on the large rod machines, have a different type connection for attaching to the coil rod.

The sectional power rodder is designed to use rods put together in sections. Rod size is 5/16-inch in diameter and is available in lengths of 36, 39, and 48 inches and are put together with a double nut coupling.

The sectional machines will be equipped with a chain drive "head" for one of these lengths and *ONLY* that length rod can be used.

The sectional machine, usually 9 to 12 horsepower, is capable of clearing lines effectively in diameters to 12 inches and distances up to approximately 750 feet. In smaller diameter lines it may be possible to extend this to 1,000 feet, if the machine's rated capacity will allow. These distances are too long for effective clearing if the sewer contains sand or grit.

The continuous rodder is capable of holding approximately 1,000 feet of one piece continuous rod. Effectiveness decreases with the larger line sizes and consideration must be given to the capabilities of the rodding machine and equipment. Most machines are powered by a 20 horsepower gas engine and use a rod with a diameter of ⅜-inch (.375 inch), other models are available which can use rod diameters up to ½-inch and lengths of 2,000 feet. These larger machines are not commonly used for clearing sewers except for special applications. Generally speaking, a .375 to .395-inch diameter rod is used.

Power rodding machines can be operated by a mechanical or hydraulic drive mechanism or a combination of both. Both styles, sectional or continuous, are basic in their design and available either as truck or trailer mounted. There are some small differences in styles, but most of these differences are relative to the individual machine's operation.

COMPARISONS BETWEEN SECTIONAL AND CONTINUOUS RODS.

1. Continuous rodding machines are quickly and easily loaded while a sectional rodding machine requires hours to couple the sections together and tighten.
2. Sectional rods are pushed through the drive head by a positive drive, not by rollers which can slip and cause wear; however, the "drive dogs" push against the individual coupling and cause wear to the "drive dogs" and coupling. Couplings on sectional rods cause more wear on the guide hose liner than continuous rods do.
3. Continuous rodders can rod greater distances than sectional rodders can and are less apt to break at great distances.
4. Couplings and nuts on sectional rods tend to work loose and require constant inspection.

SECTIONAL
VS
CONTINUOUS

5. Continuous rodders are easier to clean than are sectional rodders. Continuous care must be given to cleaning both types of rods when they are being retrieved to prevent grit from going up the roller system.
6. When a sectional rod is broken, repair can be quickly done in the field by replacing the broken section or recoupling the rod and adding a new rod only when more footage is needed. When a continuous rod breaks, repair is difficult. One style of rod requires flat spots to be ground on the rod tip for seating set screws. Filing is not recommended because of the hardness of the rod. Another style requires a short, sharp bend at the tip to fit the coupling. Often the rod will break off before a usable bend is attained.
7. A broken continuous rod in a sewer is more difficult to retrieve since the pick-up tool does not have couplings to grab. The broken end of the continuous rod cannot be reused, and possibly the remaining portion of the rod on the machine also is lost if remaining footage is too short.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 355.

6.32A What are the uses of power rodders?

6.32B What size sewers and distances can be cleared with a sectional power rodder?

6.32C List the advantages of a sectional rod.

6.32D List the advantages of a continuous rod.

6.323 Manpower and Equipment

Two operators are needed to properly operate the power rodder and three are recommended. One operator performs the actual operation and an assistant is needed for close observation of the action of the rod and guide hose at the working manhole. The third operator is needed to notify the operator when the clearing tool has reached its destination, or the location where it is removed, or where it is changed to a different tool. Minimum manpower requirements are:

1. Maintenance Equipment Operator, and
2. Maintenance Man I.

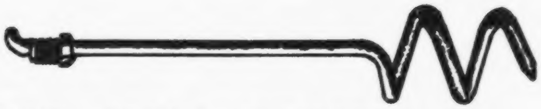
If a two-operator crew has to enter a manhole, a foreman or someone else must be called to the job site so two operators will be topside when the third operator enters the manhole.

The equipment operator should be well trained in the use and operation of the power rodder and will be responsible as well for supervision of the proper set up, safety measures and selection of the clearing tool to be used. The effective use of the selected tool will depend to a great extent upon the operator — how well the operator determines the problem at hand and how conscientious the operator may be in getting the sewer as clear as possible.

Tools and accessories are varied, but basic in design. Many have been developed on the basis of field reports and the industry continues to produce more effective new tools and techniques.

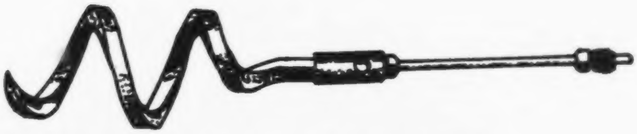
The same basic tools are used for either the continuous or sectional power rodder. These tools include root saws, square bar augers, spring blade cutters, round or square bar corkscrews, porcupines, swabs, pick-up tools, and assembly wrenches. Sketches of these tools and their uses are on the following pages.

SEWER RODDING TOOLS AND USES



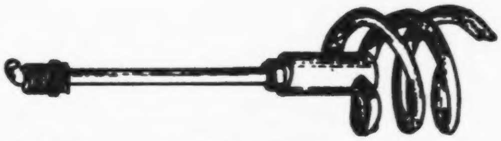
ROUND STOCK CORKSCREW

For rodding through sewers where conditions are unknown.



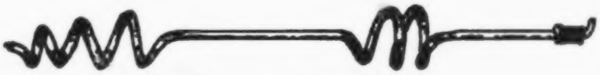
SQUARE STOCK CORKSCREW

For removing heavy root growth. Sharpened cutting edge will tear loose roots and remove other rigid obstructions when pulled backwards.



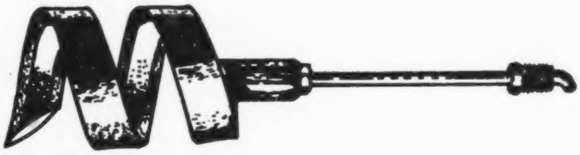
DOUBLE CORKSCREW

A double-pronged tool to remove miscellaneous obstructions.



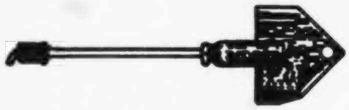
DOUBLE SAND CORKSCREW

The boring action of the corkscrew helps to pull rod through lines, impacted with sand, gravel and similar build-ups. This tool must be kept moving since it may settle into built-up material and become stuck.



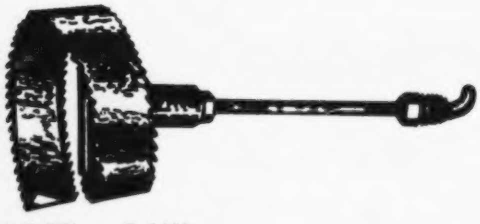
AUGER

This tool is useful in the cutting of long stringy roots and the loosening of sedimentary deposits in sewer pipe.



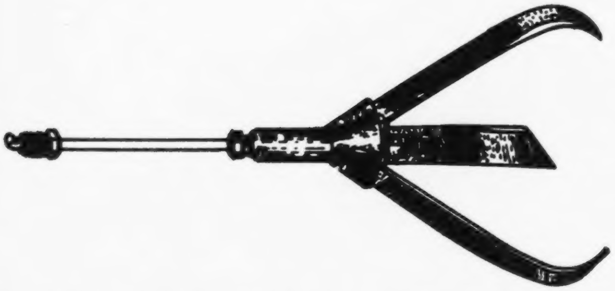
SAND LEADER

Used to guide rods across the top of built-up materials in the line by the flipping action of blades.



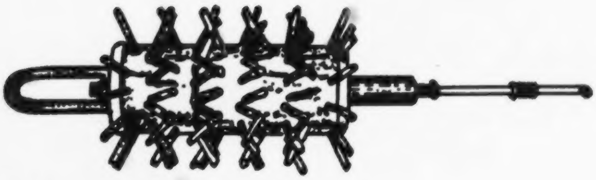
ROOT SAW

Used for power sawing of stubborn root masses in the sewer pipe.



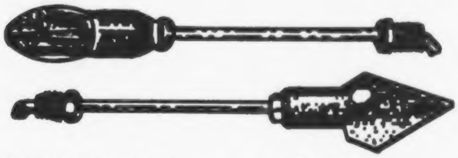
SPRING BLADE ROOT CUTTER CHUCK

This cutter with the proper size blades is used in Preventive Maintenance Type Sewer Work. Should be rotated at high speed (Power Rodding Machine) and *PULLED* slowly through the line while rotating to effect a thorough scouring of the pipe. Note: This tool is not designed to be pushed into a sewer line.



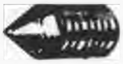
PORCUPINES

The use of turn-type porcupines is used in lines up to 12 inches in diameter and its function is to scour lines of light build-ups in conjunction with water flushing of sewer lines.



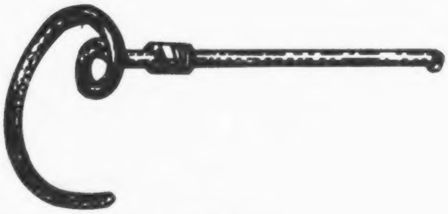
SPEARHEAD BLADES

Used in small pipes to remove hard deposits and break up hard obstruction such as glass, bottles, cans and plaster, etc.



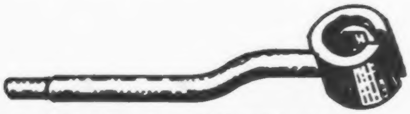
BULLET NOSE

It's designed to be screwed into end of coupler for least resistance when rodding through heavy roots, etc.



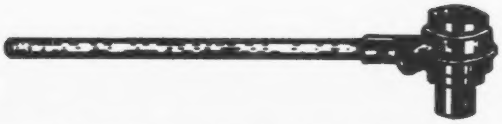
PICK-UP TOOL

Used to snare broken sectional sewer rods.



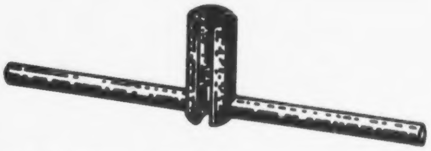
ASSEMBLY WRENCH

Used for holding and turning nuts and couplers in assembly rods and tools.



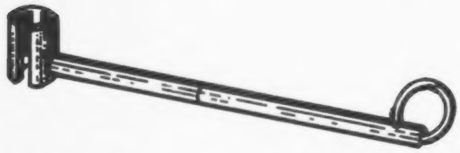
RATCHET TURNING HANDLE

Used with locking pin through pullout tool and coupler to turn rods.



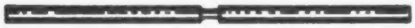
PULLOUT TOOL

Used to encircle rod coupler to push rods into or pull rods out of line.



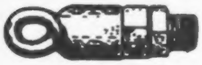
ASSEMBLY TURNING HANDLE

Used for assembling nuts and couplers for turning rods, spring loader pin engages hole in coupler.



BAR TURNING HANDLE

Used to secure into hole in coupler for turning, pushing and pulling rods.



ROD END SWIVEL

Used for pulling cables and wires through a pipe and is designed to be free turning under load at the rod end coupling.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 355.

6.32E How many operators are needed for a power rodder crew?

6.32F What must a two-operator crew do when someone has to enter a manhole?

6.32G Which clearing tool would you select to rod a pipe when conditions are unknown?

6.32H What type of tool can be used to remove grease?

6.32I Is the power rodder more effective in large or small lines?

6.324 Equipment Set Up

If a particular area or subdivision is to have roots or grease cleared with a power rodder, start at the top of the system. In so doing, any debris you may lose downstream from your work will be going into an area that you will be going to next and not into a cleared line. Be careful that any debris lost downstream does not cause a stoppage in a downstream sewer already in poor condition.

Whether rodding upstream or downstream, the set up of the power rodder will be the same, except when rodding from inlets, siphons, and other similar structures. First position the machine at the manhole so the rod guide hose is pointed in the direction you will be rodding. Most collection system operators rod only from the upstream manhole when there is no stoppage. When rodding from the downstream manhole and using small tools (spearhead blade or bullet nose), these tools will occasionally turn up house service connections instead of going up the sewer.

Since most manholes are in street areas, certain safety measures must be taken for handling traffic and insuring safe conditions in manholes. See Section 4.3, Routing Traffic, and Section 4.4, Manhole Hazards, for details. Install a leader tool or smooth coupling on the end of the rod before installing the rod guide hose (Figure 6.30). This leader tool will prevent the sharp end of the rod from damaging the interior of the rod guide hose. After installing the rod guide hose, run the rod out far enough from the end of the rod guide hose to remove the guide tool and install the selected clearing tool.

TRAFFIC ROUTING
HI! PLEASE TURN BACK AND REVIEW SECTION 4:3 ON PAGE 116

MANHOLE HAZARDS
HI! PLEASE TURN BACK AND REVIEW SECTION 4:4 ON PAGE 124

Pull the clearing tool back near the end of the rod guide hose. A rope will be fastened to the end of the rod guide hose and with this, insert the clearing tool into the sewer. Most power rodders are equipped with a rod guide hose brace to keep the hose from pushing back out of the sewer into the manhole when the clearing tool comes in contact with roots or other material in the system. Proper positioning of this brace is important since slack rod in the manhole can cause breakage and is extremely dangerous.

Pull the power rodder away from the manhole just enough to take the slack out of the guide hose. Often a hose-jack or brace is used to support the hose, especially when working in shallow manholes where several feet of guide hose could be left unsupported between the manhole and the power rodder. Install a sand trap or other suitable debris trap. If rodding upstream, install this trap in the downstream side of the working manhole. If rodding downstream, put it in the downstream side of the lower manhole. This will keep loosened roots, grease chunks or other material from going farther and possibly causing a stoppage.

Different models of power rodders may add to, or change this set up procedure slightly, but generally this procedure will cover the basic set up.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 355.

6.32J Should a sewer be rodded upstream or downstream from a manhole?

6.32K What is the purpose of the leader tool that is installed on the end of the rod?

6.32L Why should a debris trap be installed on the lower side of the downstream manhole when using a power rodder?

6.325 Tool Selection and Operation

As mentioned before, the operator (Maintenance Equipment Operator) will be responsible for selecting the proper clearing tool. A history of the sewer you are clearing will be of great help; but lacking this information, other indications of which clearing tool to use may be grease in the manhole or trees growing close to the sewer.

If the set up is being made to clear a stoppage, a good tool to start with is the round stock corkscrew. After the stoppage has been broken loose, you should have some indication of what caused it. The next tool to use depends on whether the stoppage was caused by roots, grease, or grit.

EEN E-MEENIE
MI Y-MOE

If it is a root problem, the root saw or square bar corkscrew of correct size would be used. If grease is the problem, send the corkscrew tool to the opposite manhole, remove the corkscrew and install a cutter blade of the proper size. For heavy grit deposits, the auger will loosen these deposits. Often flushing the line while using the auger is recommended, especially if flows are low during the rodding operation.

Use of saws and cutters are preferred by some collection system operators over the use of corkscrews and augers because saws and cutters allow continuous use of the sewer instead of pulling the auger or corkscrew back each time the auger picks up a load. Rotary cutters and saws break up roots and other material and allow the material to be flushed down the sewer by the flowing wastewater.

The same set up would be used if you are trying to retrieve other clearing tools lost in the sewer.

The clearing operation is now ready to begin. One operator (Maintenance Man I) can be either stationed and protected at the opposite manhole or sent there before the clearing tool gets there. The reason is two-fold: first, to make sure you have completely rodded this section of line, and second, to remove any excess roots, or change to another tool before pulling back into the line. NEVER take hold of the clearing tool until it has stopped rotating and the power rodder is shut down. Many accidents occur because precaution is not taken here. The clearing tools are sharp and can even tangle in your clothing. A rod has a tendency to coil inside the sewer. Even though the clearing tool has stopped turning, it doesn't mean the rod cannot suddenly unwind from this torque when the tool is moved. Before making any changes or adjustments, be sure the tool is backed up from any obstructions and "uncoiled" from any twists.

Most rodders are equipped with footage meters. The operator must know where the clearing tool is at all times. If you encounter an obstruction you cannot pass and a line repair has to be made, it is essential to know where to mark out the obstructed area. The footage meter is essential too in recording footage cleared for a log or record. The time will come also when a clearing tool is lost or jammed and you cannot pull it loose. Your footage meter is most important to know where to make a "dig-up" to recover the clearing tool.

Using the proper controls of the rodder, push the rod and clearing tool into the line a few feet and slowly start rotating the rod in a clockwise direction. The speed of the rod in or out and the rotation speed depend primarily on existing conditions in the sewer and also upon the experience of the operator. If you are going into a stoppage or a known root area, particular caution should be taken. The rod travel into the sewer usually can be instantly controlled, but the rotation of the rod will cause the rod to break if it becomes lodged, and it is most difficult to stop in time unless caution and alertness are taken by the operator.

Listen to the sound of the driver and tension on the rod. Learn to recognize differences in resistance, such as when obstructions are encountered. When the sound changes suddenly, back up the rod a few feet and try again. Use the same rotation, but advance the rod slower. Look, listen and feel your way when rodding a sewer.

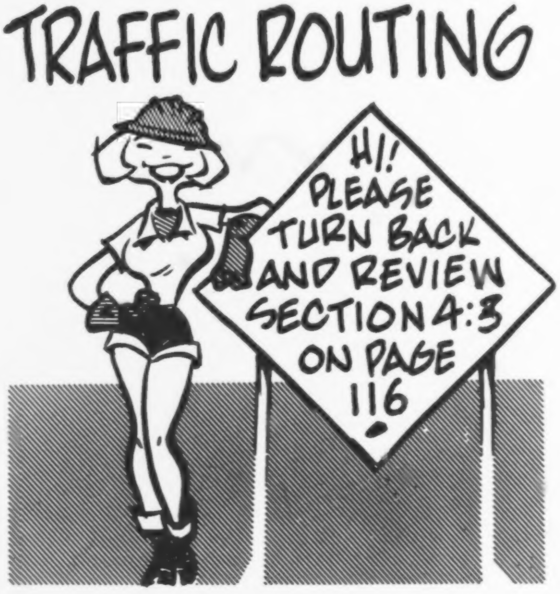
1. Do not jam the rod into an obstruction. This is the fastest way of breaking a tool or rod. Smooth, even operation is required.
2. Do not rotate the rod in one position for extended periods. Heat builds quickly where the rod bends in the manhole and will fatigue and break. Keep the rod moving in or out while rotating.
3. Experience will guide the operator as to the amount of torque that can be applied during the clearing operation. Generally speaking, extreme care should be taken in rotating the rod until 50 feet or more of rod is in the line.
4. If the rod should break, again make sure all the torque is out of it before handling it.

After reaching the opposite manhole and the tool is not changed, usually a faster rotation on the way back will catch places missed on the way in.

Again, do not sacrifice clean lines for footage. One run may not be enough to get the sewer clean, especially with roots. The effectiveness of the clearing operation can be increased in problem areas by dumping or running water into an upstream manhole during the clearing operation. A flow in the sewer is essential for cooling the rotating tool and for flushing the sewer.

A slight variation of this procedure can be used when rodding from the upstream manhole and there are no stoppages. Send a small tool to the downstream manhole and then attach a full size tool (a root saw or spring blade root cutter if roots are a problem). This technique keeps the rod straight in the sewer by pulling on the clearing tool, instead of pushing which causes the rod to coil in the sewer. Advantages of this procedure include the application of greater pressure on partial obstructions in the sewer and increased rod life.

After completing the first section of line, remove the hose guide jack and pull the clearing tool and hose from the manhole. If debris has built up at the trap, check for gases found in sewers, ventilate manhole, and have an operator properly harnessed descend into the manhole. With the trowel or manhole scoop, clean the dislodged material out of the channel and with the bucket, remove it from the manhole and make any necessary clean up around the working area.



If you are going to the next manhole to continue clearing, usually the rod guide hose can be left attached with the clearing tool. The power rodder often is equipped with hose hangers for this purpose, so the rod guide hose and tool are ready for the next set up. This time-saving decision is up to the machine operator and depends on the specific equipment set up because a move of some distance might tend to damage the hose. Some machines are equipped with a swivel connection for the rod guide hose so a bend is eliminated in this operation. By simply removing the tool and pulling the rod back into the machine, the hose is flexible and can be layed around and alongside the machine. This is only one of a number of timesaving short cuts which in the long run saves considerable time and wear and tear on the equipment.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 355.

6.32M How do you determine which clearing tool to use?

6.32N Which tool would you use to clear a stoppage?

6.32O After a stoppage has been cleared, which tool would you use?

6.32P What precaution should be taken *BEFORE* changing to another clearing tool at a manhole when the rod is still in the sewer?

6.32Q Why must you always know where the clearing tool is in the sewer?

6.32R How would you determine the speed of the rod in or out and the rotation speed?

6.32S Why is water sometimes added to the opposite manhole during power rodding?

6.326 Recovery of Broken Rods

Recovery requires practically another set up procedure. How quickly you retrieve the rod depends on several factors. When a rod breaks, measure the amount of rod pulled back to determine the approximate location of the broken rod. If you are using a rodder with sectional rods, it's only a matter of removing the broken stub of a rod at the coupling and installing the pick-up tool. With a continuous rod it is more complicated because you have also lost your tool coupling with the rod. Depending on the style of rod coupling used, you will either bend a new top on the rod with a special bending tool or perhaps the style of coupling will require a flat spot or dimple in the rod for a set screw. Needless to say, extra couplings have to be handy.

Then a fishing expedition begins to try to pick up the broken piece. The pick-up tool is placed in the sewer the same as a clearing tool. Send the rod into the sewer slowly and with slow and steady rotation. "Feel" your way and most often you can tell when resistance is encountered. At this point, stop rotation; and without letting the rod "unwind", pull steadily out of the sewer. The pick-up tool is so designed to screw around the lost rod and become snug. Perhaps several attempts will have to be made, but the rod must be removed, even if by dig up. If you have a clearing tool lodged, often counter-rotation of the rod reel is all that's needed to get it loose. Go in again, only more cautiously.

Rods may break in the reel section of the rodder, especially with a sectional rod. *WHEN MAKING THIS REPAIR BE VERY CAREFUL.* The rod is under some tension and can be dangerous if it gets away from you.

Use gloves and keep the end of the rod away from your face. Most accidents using power rodders involve the rod or clearing tools. Extreme care and proper instruction in attaching tools and rod repair must be followed.

There will be many different problems and a standard answer cannot be given for any specific problem. What works in one situation may not in another. Experience and observation will overcome most problems and hazards. Broken clearing tools often can be picked up with another clearing tool or perhaps flushed out, particularly if a high velocity cleaner is available.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 356.

6.32T What tool is used to recover a broken rod?

6.32U What is done if a broken rod can't be recovered with a pick-up tool?

6.327 Precautions and Safety

WARNING

NEVER HANDLE THE ROD UNDER TENSION. TREAT TWISTED RODS VERY CAREFULLY. THEY ARE **VERY DANGEROUS**.

Once again, emphasis needs to be placed on speed of rod travel and rotation. These two items combined, break or twist most rods. Most machines will be capable of holding close to 1,000 feet of rod which is quite heavy. With the weight of the rod on a spinning reel, considerable twisting power is developed; but it also takes some few moments to get it stopped. An operator can get through some difficult stoppages or root problems with skill and patience.

Do not attempt to rod distances greater than from one manhole to the next unless absolutely necessary. Trying to avoid extra set up time can be much more dangerous than normal operation.

When working on a rodding crew, required procedures of operation must be established and followed for each individual. You must know your own job and the jobs of everyone else on the crew so everyone can be familiar with the over-all operation.

With constant use, rods do suffer from fatigue; and when a rod breaks, it's likely to be in the sewer. Avoid turning the rod without rod travel in the sewer. Heat builds up very quickly at any bend when the rod is turning. Therefore keep it moving at all times if possible.

Porcupine cleaning tools are available for attachment to the power rodder. Their use is not discussed because of potential safety hazards. Other tools can do a similar job in a safer manner. If a porcupine must be used, a winch and tag line must be used for safety.

6.328 Maintenance of Rods and Equipment

Sectional rods should have the rod couplings kept tight at all times. These will work loose while rodding, and a visual inspection by the operator even while working the machine will often pick up a coupling that is loose.

Make a practice of running the rod out on top of the ground on occasion and inspect the rod for bent pieces and loose couplings. When they are allowed to stay loose, the rod will wear and become weak at that point. Do not throw used couplings away — they can be reused.

Continuous rods are driven by rollers pressing on the rod. A clearing tool in the form of a clamp is furnished with the machine and has a very important function. A coarse piece of cloth or similar material is kept in the clamp tool; and when you are ready to pull the rod back into the machine, clamp this tool around the rod at the head of the machine and it will wipe the rod clean as it is returned to the reel. If this grease and grit are allowed to continue passing on into the pressure rollers, they will build up and cause wear on the rod.

Even with a clean rod, the pressure of its being rolled back and forth causes some wear. Therefore the torque on these drive rollers has to be checked and reset. Specifications for the particular machine are furnished by the manufacturer.

Always avoid sharp bends in the guide hose regardless of the type of machine. The metal liner can become bent and distorted. Inspect the guide hose frequently and carefully for wear, mounting, and mechanical damage such as crimping.

Be completely familiar with the clearing machine. Know what operating and maintenance procedures the unit requires.

Inadequate maintenance before rodding a sewer can result in considerable time lost attempting to recover a broken rod. The necessary maintenance items can easily be done on the job:

(SECTIONAL RODDER)

1. Inspect for loose rod couplings.
2. Keep drive head chain tight.
3. Inspect for worn drive dogs and improperly adjusted belts.
4. Look for "stacking" of the rod on the reel when bringing the rod back into the reel cage.

(CONTINUOUS RODDER)

1. Maintain proper torque on the driver rollers.
2. Examine wear on the rod guide bushings.
3. Inspect for sharp teeth on drive gears. This indicates wear or needed adjustment.
4. Look for leaky hoses and fitting on hydraulic units. Maintain proper oil level in the hydraulic oil tank. Keep the hydraulic oil filter clean.
5. Fluctuating oil pressure may be due to hot hydraulic oil. This may or may not be just from continuous use. Be suspicious and check for other problems.

Always keep the rodder, tools, and accessories as clean as possible. The engine should have the maintenance and care as recommended by your shop foreman or manufacturer's directions. For more information, see Section 6.43, Rodding Machine Maintenance.

With proper maintenance and care the rodding machine will do a good job of clearing a sewer. Like any other machine it has its limitations and as experience is gained in the operation, you will know what it can or cannot do.

6.329 Records

See Section 6.18, Records.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 356.

6.32V Why must extreme care be used when handling a rod or clearing tool?

6.32W Why should a rod occasionally be run out on top of the ground?

6.32X Why should the rod be cleaned when it is returned to the reel?

6.32Y Why must everyone on a rodding crew know their own job and the jobs of everyone else on the crew?

6.32Z What maintenance should be done on the engine of the power rodder?

6.33 Hand Rods

With all of the modern equipment available, it is still necessary to have hand rods available (Figure 6.31). One of the first reasons is that hand rods can be used when and where the modern methods cannot be used effectively. Hand rods are a quick and simple answer for many stoppages. Hand rods are often used on "service request" trucks and for "off-hours" stoppage calls. They are used extensively for emergencies at nights or during weekends. After the stoppage is cleared, thorough cleaning can be done at a later date.

Often maintenance crews will carry a reel of hand rod on the same work truck used in conjunction with a power rodder. If when clearing a particular area the power rodder cannot be put to use, such as an easement, the hand rod can be used and not leave a section of sewer uncleared and likely forgotten. Also a hand rod can be used from the opposite manhole to free a stuck or broken power rod.

Other maintenance crews may do only hand rodding. This is not uncommon in sanitary districts with hilly areas or in very small districts where the total length of sewer in the system does not warrant routine clearing with other types of equipment. Other factors may be involved, but the main point is that hand rod methods are here to stay at least in the foreseeable future.

6.331 Manpower and Equipment

The particular job often will dictate how many operators will be needed. However, if a crew is essentially doing only hand rodding, at least two operators are recommended:

1. Maintenance Man I, and
2. Maintenance Man II.

A three-operator crew is required if one operator has to enter a manhole. Usually rod crews or "service request" crews consist of two operators and they never enter a manhole. If the need arises for someone to enter a manhole, a third operator must be available and added to the crew *BEFORE* anyone enters a manhole.

The hand rods are regular sectional rods as used on power rodders. Usually the rod length is 36-inches. This length is easy to control and simple to keep track of footage or number of sections used. The rod is stored in a shallow reel approximately four (4) feet in diameter and so constructed to keep the rod contained on the reel. It is equipped with a removable tripod which allows the reel to be set up quickly near the work site at an angle convenient for operation. When the reel is properly set up on the tripod, the rod can be pulled off or onto the reel allowing the reel to turn freely. Many work trucks are equipped with this reel fastened to the truck. When rodding is needed where the truck cannot be taken, such as an easement, sections of the rod are simply removed from the reel and pulled to the working area by hand.

Hand rod trailers are available as well that are compact and have the reel mounted at an angle convenient for use. These trailers also have a box for tools and a rack for a three-wheel, gas-powered unit to turn the rod. This power drive is essential, especially when other rodding equipment is not available or usable. The power drive has a lightweight engine with a gear reduction and control which allows the end of the rod to be attached for turning. With a hand control, rotation of the rod can be accomplished to cut roots or make penetration into stoppages very similar to the operation of large power rodders, except the distance of penetration is not as great.

Other than these basic items, reel, rod, power drive, and perhaps a trailer unit, tools would include root saws, augers, cutter blades, pick-up tool, assembly wrench, turning handle, rod guide tube and extension pipe, guide tube jack, sand traps, manhole shovel, debris bucket and hand line, and a manhole pick, hook or lid lifter.

6.332 Equipment Set Up

Where you are going to be set up will govern the measures for safe working conditions. Refer to Section 4.3, Routing Traffic and Section 4.4, Manhole Hazards, for procedures to insure safe working conditions with regard to traffic routing and manhole work.

TRAFFIC ROUTING
HI! PLEASE TURN BACK AND REVIEW SECTION 4:3 ON PAGE 116

MANHOLE HAZARDS
HI! PLEASE TURN BACK AND REVIEW SECTION 4.4 ON PAGE 124

When using a hand rod it is not uncommon to have a number of feet of bare rod exposed on top of the ground or street. Because of the nature of this method of clearing, this does occur and consideration and care must be allowed in the set up. Loose ends in a twisting operation can catch and twist and then let go with disastrous effects. Even if you are in an easement area, care must be taken not to cause damage to flowers, shrubbery, lawns, fences, and gardens with the loose rod.

Ventilate manhole and test for toxic gases, explosive gases, and oxygen level. Determine the depth of the manhole. Assemble sufficient pipe to the rod guide tube to allow the curved channel portion to firmly rest in the sewer and enough protruding above the street level to allow for working conditions, usually about 18 to 24 inches. To the exposed end attach the flared fitting through which the rod will be fed. Firmly anchor the rod guide tube to the bottom of the manhole.

Have the reel, whether truck, trailer or tripod mounted, situated several feet from the working manhole. Thread the rod through the assembled rod guide tube, install the clearing tool, then insert it into the sewer, upstream or downstream whichever method is chosen. If going upstream, install a sand trap or debris trap in the downstream manhole. If going downstream, the trap would be installed in a like manner at the lower manhole. The guide tube brace or yoke is installed to hold the tube in place at the top of the manhole. The decision to rod upstream or downstream is determined by the rodding crew in the field. Three factors are considered when trying to clear a stoppage:

1. Usually it is easier and cleaner to rod into a dry downstream manhole than an overflowing upstream manhole.
2. Try to rod the shorter distance to the stoppage. Distances are estimated on the basis of past history, good records, and on-site observations.

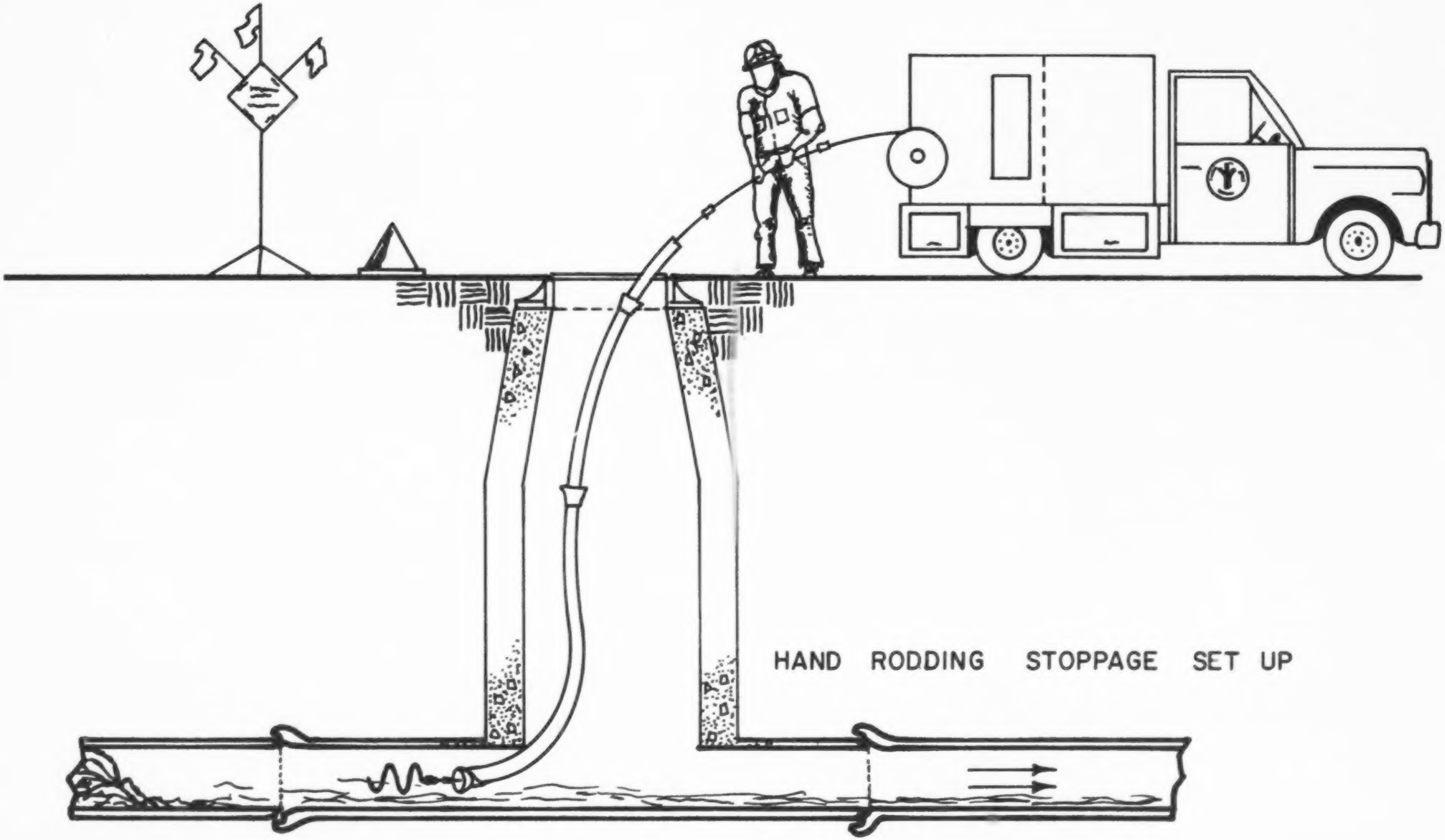

HAND RODDING STOPPAGE SET UP

Fig. 6.31 Hand rodding operation

3. If rodding upstream, what will happen when a stoppage breaks loose under a high head? If the operation is being observed properly, you can hear the flow coming and get out of the way. If rodding upstream into a stoppage with a high head behind it creates a safety hazard, rod from the upstream manhole. Always try to keep control of the rod at all times. See Section 6.334, Precautions and Safety.

Set up procedures for hand rodding vary with the different problems involved, but this procedure will fit most needs.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 356.

6.33A When are hand rods used?

6.33B How many operators are on a hand rodding crew?

6.33C Which has the greater penetration into a sewer, a hand rod or a power rod?

6.33D What precautions must be taken when a bare rod is exposed on top of the ground or street?

6.333 Operation

For routine clearing, the tool to be used at the end of the rod would depend somewhat on the sewer's condition. As with power rodding, if some history or prior knowledge of the situation is available, it takes away the guesswork. Both the square bar auger and root saw often are used for routine clearing, so one of these could be used to start clearing the sewer. If roots are suspected, perhaps it would be advisable to rotate the rod from the beginning so as not to miss any. If this method is decided upon, pull off approximately 25 feet of rod from the reel and disconnect with assembly tools (Maintenance Man I). Insert the end of this rod through the power drive unit and start rotation — one operator running the power drive (Maintenance Man I) and one operator feeding the rod into the guide tube (Maintenance Man II). When the rod is worked into the sewer, attach another 25 feet of section and repeat the operation.

Admittedly, this is a slow operation. As indicated previously, in some "hard to get at" areas or where other equipment is not available, this method is still needed.

When the clearing or rodding tool has reached the opposite manhole, the rod often can be pulled out by hand, especially if you are working upstream. If not, rotate the rod with the power drive or turning handle and pull on the rod at the same time. If sufficient space is available, long lengths may be removed at a time, but care again must be given to traffic or other hazardous conditions. If the rod can be pulled by hand, simply attach it to the rod remaining on the reel and roll it up as it is pulled from the sewer. Disassemble the guide tube brace, clearing tool, and guide tube. Clean the material from the manhole and remove the debris trap. If it is necessary for an operator to enter the manhole, the operator must be properly equipped with safety harness and hard hat. Be sure to test for gases found in sewers before entering the manhole and keep the manhole ventilated. Two operators must be topside whenever anyone enters a manhole.

Many uses of hand rods can be considered in addition to the method outlined above. One of these would be to "prove" the sewer in routine clearing. This would be to simply push the tool, auger or saw, up to the next manhole and back again without turning; if it goes by hand, fine. Otherwise, push it as far as possible by hand and then turn it only enough to get the tool through. This, of course, gets footage faster, but you may also pass up roots or other material. If this method is chosen, you can go downstream much easier than upstream.

Turning handles are often used for small trouble spots rather than using the power drive unit. If roots or other obstructions are encountered where the turning handle cannot be used, then the power drive has to be used.

To clear stoppages with a hand rod, follow a procedure similar to the one described in this operation section. Whenever possible, start at the manhole below the stoppage; and after installing a suitable debris trap, work an auger of a size smaller than the line size, up to the stoppage. If possible, hand turn auger into the stoppage with a turning handle until the rod is tight; and with torque still on the rod, pull back. This usually will dislodge a stoppage. Try to remove the dislodged material so it won't cause another stoppage downstream.

A sudden charge of wastewater will be noticeable in the working manhole when a stoppage is cleared. After this water has subsided, run the tool back and forth in the stoppage area and then pull out the rods and tool. If hand turning the rod doesn't clear the stoppage, put the gasoline driven power drive unit on the rod and use this unit. If this procedure doesn't work, try the power rodder (Section 6.32). After the stoppage has been cleared, inspect the upstream manhole to be sure the flow is normal and clean up any overflowed area.

In larger sewers the stoppage often occurs in the upstream manhole rather than in the sewer. Clear the stoppage from the downstream working manhole and then clean the upstream manhole after the water drops.

If the stoppage takes place during normal working hours, a thorough cleaning job should be done on the sewer at that time.

Procedures for clearing and set up are essentially the same for all problems where hand rods are involved. Some short cuts are used, of course, and many are not recommended mostly because safety measures are sacrificed or equipment can be damaged. Some precautions are discussed in the next section.

6.334 Precautions and Safety

One particular problem occurs all too often when hand rodding, that is, having too much loose rod unattended, or used in an unsafe method. Because it is time consuming to be continually fastening short sections of rod together, the tendency is to use a long section. If proper care and attention are given to this loose rod, a certain amount of looseness is acceptable. However, the "problem" at hand all too often takes precedence. Someone can be seriously injured and considerable property damage done should a car run over and catch hold of a loose piece of rod.

Another problem becomes evident when using the power drive unit. If too much distance is allowed between the power drive and the manhole rod guide tube, a loop can easily and suddenly be thrown in the rod and someone will be injured.

NEVER USE RUBBER GLOVES WHILE HANDLING OR GUIDING A ROD THAT IS TURNING. EVEN IF THE ROD IS WET, IT WILL SIEZE THE PALM OF THE RUBBER GLOVE AND, IF NOT STOPPED IN TIME, EITHER TWIST THE GLOVE FROM THE OPERATOR'S HAND OR CAUSE INJURY. Use a manhole hook or other device to guide a turning rod.

When working a rod upstream to a stoppage, be cautious when the stoppage is broken loose. Especially if the grade of the sewer is steep. The sudden surge of stored water rushing downstream can shoot up through the rod guide tube and get someone wet.

On steep grades where a root mass has been broken loose, it is not uncommon for the water pressure to literally force the rod back out the guide tube with such force it cannot be held. In that case all you can do is control the loose rod to the best of your ability.

6.335 Records

In districts where hand rodding is primarily in easements, it probably isn't done too often, especially those sewers requiring only routine maintenance. Work in these areas must be properly recorded, the same as in the troublesome areas. Emphasis has to be continually made to require systematic recordkeeping. All too often we keep track of the problems and let the rest go, until they too become a problem. All clearing must be properly recorded in accordance with Section 6.18, Records.

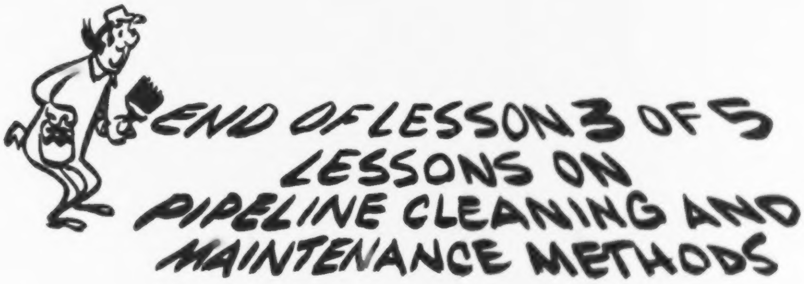
QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 356.

6.33E What kind of tool is used at the end of the rod?

6.33F What would you do if hand turning a rod did not clear a stoppage?

6.33G What precautions must be considered when working a rod upstream to clear a stoppage?



DISCUSSION AND REVIEW QUESTIONS

Chapter 6. PIPELINE CLEANING AND MAINTENANCE METHODS

(Lesson 3 of 5 Lessons)

Write the answers to these questions in your notebook before continuing. The question numbering continues from Lesson 2.

14. Under what conditions would you use mechanical cleaning techniques?
15. Why are power bucket machines usually not scheduled on a regular basis?
16. How can you determine when a bucket is full?
17. How would you select a tool for a power rodder?
18. How is a power rodder operated in a sewer?
19. When would you use a hand rod?

CHAPTER 6. PIPELINE CLEANING AND MAINTENANCE METHODS

(Lesson 4 of 5 Lessons)

6.4 CLEANING EQUIPMENT MAINTENANCE

6.41 Need for Cleaning Equipment Maintenance

Water and dirt are the two worst enemies of mechanical equipment; therefore, extra special attention must be given to sewer cleaning and inspection equipment. To do our jobs quickly and effectively, our equipment must be properly maintained and repaired at all times.

Equipment manufacturers provide the purchasers of their equipment with manuals that explain how to operate and maintain their equipment. Your job is to learn how to properly operate and maintain the equipment and be sure everyone follows these procedures. This section outlines the procedures for maintaining bucket machines, rodding machines (power rodders and hand rodders) and high velocity cleaners. The ideas presented can be applied to developing preventive maintenance procedures for balling equipment, sewer scooters, and TV inspection equipment.

6.411 Objective of Cleaning Equipment Maintenance

The objective of cleaning equipment maintenance is to *KEEP EQUIPMENT IN GOOD REPAIR AND EFFICIENCY AND TO HELP PREVENT EQUIPMENT FAILURE.* To accomplish this objective we need tools, time, and talent.

TOOLS:	Without the proper tools, even the best mechanic cannot do a good job even with ample time.
TIME:	You can have a tool box full of the proper tools and the "know-how", but we never seem to have time for preventive maintenance until it is too late and the equipment breaks down. Equipment failures are costly in terms of repair costs, hazards to operators, and working time lost by crews.
TALENT:	Most crews can find the "time" for preventive equipment maintenance. Try to use the talent and knowledge that comes from the manufacturer and from the experience of operating the equipment to develop and implement an effective equipment maintenance program.

6.412 Who is Responsible?

The crew foreman or the equipment operator (Maintenance Equipment Operator) is responsible for the proper maintenance of cleaning equipment. Report worn, broken or lost parts of equipment immediately so that replacements can be ordered. Regardless of your job, try to have the equipment used by the crew you work with properly maintained at all times. Your job will be easier and more enjoyable if you are not always fighting with equipment that doesn't operate properly or is always broken.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 356.

6.4A Why must cleaning equipment be properly maintained at all times?

6.4B How can an operator learn how to maintain cleaning equipment?

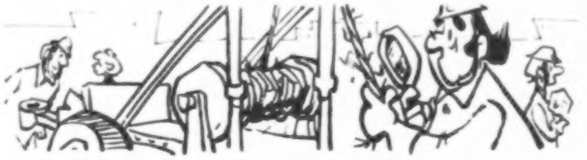
6.4C What is the objective of cleaning equipment maintenance?

6.4D What are the three essential factors for an effective equipment preventive maintenance program?

6.4E Who is responsible for the equipment maintenance program?

6.42 Bucket Machine Maintenance

Bucket machine clearing procedures require special care of the equipment. Break down and failure of equipment often results in costly repairs.



6.421 Maintenance Tools

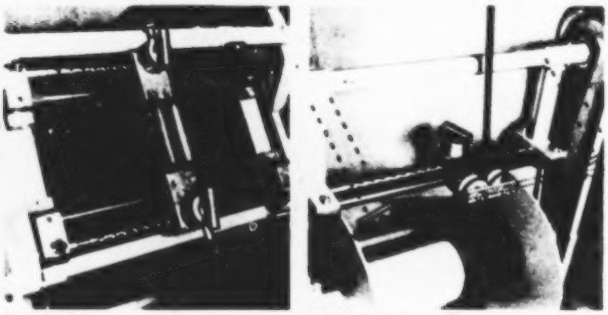
Considerable time and effort can be saved if enough tools are kept on the job for crews at both the upstream and downstream manholes. Often these crews are a considerable distance apart, especially when working in easements because some manholes may not be accessible in backyards.

Necessary tools include pipe wrenches, crescent wrenches, pliers, screwdrivers, Allen wrenches, hack saw, chisel, hammer, cable cutter, extra oil squirt can, grease gun, wire brush, extra cable clamps, clevis, pins and wiping rags.

6.422 Maintenance Procedures

The following tasks must be done regularly or when indicated for effective bucket machine maintenance.

1. Keep cable scroll and level wind system (Figure 6.32) well oiled. *THE NUMBER ONE PROBLEM IS LACK OF PROPER LUBRICATION.*
2. Keep oil or grease cups full and chains lubed.
3. Inspect belt tension, chain tension, and gear clearance. *NOTE:* Record any *WEAR ON SPUR GEARS* (Figure 6.33).
4. Lube spindles of lower rollers often, especially if they are in contact with water. Make sure they have clearance and turn properly so the cable doesn't slide and cut grooves.



DUAL SCROLL

FLOATING SCROLL

DUAL SCROLL (Truck-Loders)

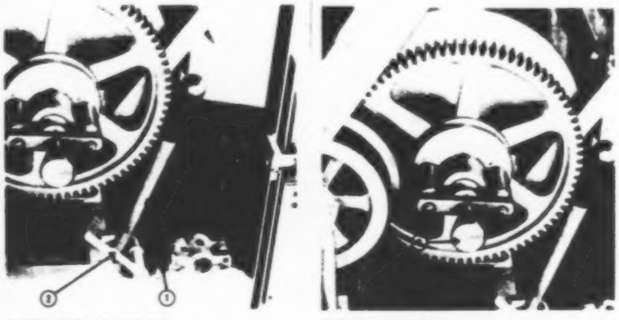
Heavily reinforced dual scroll features two synchronized scrolls and follow dogs giving a firm, steady guide to properly wrap the cable on main cable drum.

FLOATING SCROLL (Pull-in Machines)

Hinged floating scroll with roller guides compensates for each wrap of cable on the cable drum. Keeps cable in a direct line from upper cable sheave through level wind to cable drum.

Fig. 6.32 Cable scroll and level wind system

(Courtesy of Municipal & Utility Division, Rockwell International)



SAFETY BOOSTER CLUTCH

SURE-LOCK CLUTCH

SAFETY BOOSTER CLUTCH

The safety operating lever (#1) controls bucket travel. At point (#2), tension is held on the operating lever at a predetermined speed of bucket travel. The tension is adjustable, and under overload conditions the belts will slip, thus protecting pipe and machine.

SURE-LOCK CLUTCH

Positive engagement of the bull gear drive to the cable drum is accomplished by means of two heavy hardened pins which lock into two sleeved, hardened holes in the bull gear. A slight pull and twist on the knob (#3) disengages the gear; a reverse twist re-engages.

Fig. 6.33 Bucket machine spur gears

(Courtesy of Municipal & Utility Division, Rockwell International)

5. Watch for loose cable clamps and frayed cable. Tighten all cable clamps at the start of each day.
6. Look for loose rivets on buckets, badly worn bails and clevis eyes. Turn these into the shop for hard-facing and repair.
7. Keep pipe threads clean and oiled on extension pipes. Keep extra couplings on exposed pipe thread.
8. Keep stabilizer legs in good operating condition. *IF A BIND STARTS, GET IT STRAIGHTENED NOW!*
9. Keep legs locked "up" when traveling.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 356.

6.4F Why should bucket machine crews have enough tools for crews at both upstream and downstream manholes?

6.4G What is the number one maintenance problem with the cable scroll and level wind system?

6.4H When should cable clamps be tightened?

6.4I What should be done when a bend is observed in a stabilizer leg?

6.43 Rodding Machine Maintenance

Preventive maintenance for all rodding machines is similar, but some aspects depend on the type of machine. Maintenance procedures are outlined in this section for sectional and continuous rodders and hydraulic units. Be sure to read and understand the equipment manufacturer's instructions and follow them.

6.431 Maintenance Tools

Some of the tools used to maintain rodding machines include assembly wrenches, crescent wrenches, Allen wrenches, screwdrivers, pliers, hack saw, file, oil squirt can, grease gun and wiping rags.

6.432 Sectional Rodder

1. Daily.
   a. Inspect tension of drive head chain. Tension must be tight. Why? If loose, drive dogs tend to ride up and over rod couplings.
      1) Make sure chain track clearance is not too great.
      2) DO NOT turn adjusting turn-buckle without loosening bearing plate.
   b. Inspect wear of drive dogs. Why? If badly cupped, rod coupling will tend to hang up.
2. Inspect
   a. Belt tension and wear.
   b. Vari-speed control.
   c. Drive chains to sprockets.

3. Forward — Reverse Transmission (Snow-Nabst)
   a. Oil level (machine oil only as specified by manufacturer, *NOT MOTOR OIL*).
   b. Firm IN-OUT, without drive head creeping. When adjusting remember that if equipment has cast iron bands inside, they will break easily. Some equipment has a cast iron guide ring or support instead of a band.
4. Tight Rod Couplings
   a. *VISUAL INSPECTION* while in operation. Stop operation and tighten as necessary.
   b. Periodically inspect all rod couplings. Get rid of those that are severely worn or damaged and save the rest for rescue.
5. Stacking of rod on reel. *VISUAL INSPECTION* by operator when returning rod to wheel.
   a. Proper adjustment of rod guide tube and rollers prevents jamming or couplings catching on travel out.
   b. Wear on funnel of rotating guide tube.
   c. Wear on tube rollers.

OPERATOR PREPARING FOR VISUAL INSPECTION

6. Brake band or disc brake blocks.
   a. Inspect for wear.
   b. Replace before rivets cause drum damage.
7. Rod hose guides.
   a. Do not shove rod out without at least a coupling on the end, preferably a bullet tool.
   b. Keep slack out of hose guide when working shallow manholes.

6.433 Continuous Rodder

1. Proper torque on the drive rollers frequently depends on rod wear. Inspect for slippage while in use. Adjust torque when needed or wear will be excessive on rod and rollers. Also performance of rodder will be poor.
2. If combination with gears for drive head.
   a. Tooth clearance of gears.
   b. Sharp or pointed teeth.
   c. Worn gear bushings.
   d. Broken gears.
   e. Slack on reverse.
   f. Gear chatter.
3. Wear of rod guide bushings. Worn bushings tend to shave the rod.
4. Keep rod clearing tool in use, replace pads often. Grit combined with grease tend to shorten rod life.

6.434 Hydraulic Unit on Rodding Machine

1. Look for and repair leaky fittings and hoses.
2. Keep oil filter clean (some filters have a warning type gage).
3. Maintain proper hydraulic oil level (this is particularly important in hot weather).
4. Replace cracked, chafed, or worn hoses.

For more information, see Section 6.328, Maintenance of Rods and Equipment.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 356.

6.4J Why must the tension on the drive head chain of a sectional rodder be tight?

6.4K What does the torque on the drive rollers of a continuous rodder depend on?

6.4L Hydraulic units require what maintenance?

6.44 High Velocity Cleaner Maintenance

To properly operate and maintain a high velocity cleaner, the operator must be completely familiar with all aspects of the unit. Read and understand the manufacturer's instructions for proper maintenance procedures.

6.441 Maintenance Tools

Tools should include pipe wrench, large crescent wrench, grease gun (special grease recommended for pressure swivel), screwdriver, a good grade of plastic tape, plus other hand tools found in a well equipped tool box.

Special tools needed to maintain the pressure pumps are provided by the manufacturer.

6.442 Continuous Considerations

Whenever you are operating a high velocity cleaner, always be alert for:

1. Odd or suspicious sounds from:
   a. Intake valve seats,
   b. Relief valve leaking (squeal), and
   c. Belt slippage.

2. Higher or lower than usual RPM to maintain pressure. May be caused by:
   a. Intake valve partially closed,
   b. Air leaking into system,
   c. Plugged *ORIFICE*[6] in cleaning nozzle,
   d. Belts slipping, and
   e. Faulty by-pass pressure valve.
3. Sluggish reel return. May be caused by:
   a. Low hydraulic oil supply,
   b. Filter needs replacing,
   c. External or internal leak in a hydraulic control, and
   d. Foreign particles in the directional valve. (Filter should catch particles.)

6.443 Daily

1. Keep all equipment and accessories clean.
   a. Tool compartments.
   b. Engine compartment
      1) Wipe up oil and grease
      2) Paint rust spots when they appear
2. Hold Tank
   a. Drain to prevent
      1) Rust
      2) Sand or dirt deposits. Always flush hydrants briefly before filling tank.
   b. Clean tank strainers
3. Oil Levels
   a. Engine
   b. Pressure pump
   c. Hydraulic-oil tank
4. Inspect belt tension and packing glands. (See Chapter 9, Equipment Maintenance, Section 9.3, Pumps, in Volume II).
5. Lube drive chains and water pressure swivel.
6. Tape splits in hose.
7. Look for worn or plugged orifices in nozzle.
8. Inspect nozzle carrier. Nozzle carrier keeps nozzle off bottom of pipe.

6.444 Cold Weather Maintenance

1. Drain pump daily. Use air pressure to drain pump if necessary.
2. Cover rear canopy openings. A small electric heater will help keep equipment from freezing.

6.45 Equipment Engines

Equipment engines require special attention so they will operate when needed. Develop a regular maintenance program and follow manufacturer's recommendations. The items listed below are important considerations for proper care of engines used to operate cleaning equipment.

1. Always be sure oil and water levels are in proper range *BEFORE* starting unit.
2. Use a fresh supply of the proper grade of clean gasoline.
3. Change oil and air filters according to manufacturer's recommendations.
4. Exercise (operate) equipment weekly if not used.
5. Use proper type of oil in engines, transmission and for lubrication.
6. Keep battery terminals clean and battery charged for engines with electric starters, especially during winter months.

---

[6] *Orifice (OR-uh-fiss). An opening in a plate, wall or partition.*

QUESTIONS

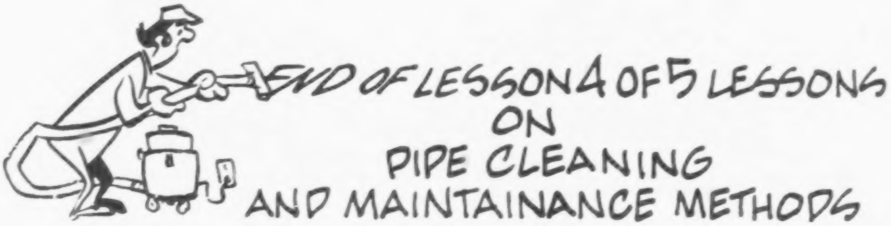
Write your answers in a notebook and then compare your answers with those on page 356.

6.4M Why must the operator of a high velocity cleaner be completely familiar with the unit?

6.4N When operating a high velocity cleaner, you should always be alert for what kinds of problems?

6.4O What oil levels should be checked daily?

6.4P What items must be considered during cold weather maintenance of high velocity cleaners?



DISCUSSION AND REVIEW QUESTIONS

Chapter 6. PIPELINE CLEANING AND MAINTENANCE METHODS

(Lesson 4 of 5 Lessons)

Write the answers to these questions in your notebook before continuing. The question numbering continues from Lesson 3.

20. Why should pipeline cleaning equipment be maintained?
21. How would you maintain pipeline cleaning equipment?
22. What maintenance items should be considered continuous when you are operating a high velocity cleaner?
23. How would you maintain equipment motors used to operate cleaning equipment?

Chapter 6. PIPELINE AND MAINTENANCE METHODS

(Lesson 5 of 5 Lessons)

by Walt Driggs and John Brady

6.5 CHEMICALS

6.51 Uses of Chemicals

Chemicals can be very helpful aids for cleaning and maintaining wastewater collection systems (Figure 6.34). Proper application of effective chemicals can be used to control roots, grease, odors, concrete corrosion, rodents, and insects. The purpose of this section is to indicate how to determine if chemicals might be effective and how to select, apply and evaluate the effectiveness of chemicals. Where specific chemicals are mentioned, trade names are provided solely for illustrative purposes.

6.52 How to Select Chemicals

6.521 Words of Caution

Many people are reluctant to try chemicals because of past unfortunate experiences involving exaggerated claims. Did you ever hear the story about the salesman selling a caustic and aluminum shaving compound? He claimed his chemical would unplug stoppages. The question was asked, "What will this chemical do to roots?" He replied, "When you pour this chemical into a manhole, it starts to boil and churn. The aluminum shavings will move so fast they will cut the roots off at the edge of the pipe." This is an example of a false claim.

Look out for exaggerated claims by promoters. No chemical will stop odors, remove roots, or repair breaks in sewers. Some chemicals may cause more damages than benefits. For example, you may clear a kitchen drain trap with a half a cup of chemical. To clear a similar stoppage in a 36-inch sewer would require tons of chemicals. This procedure would be very expensive and could cause extreme hazards downstream.

Two very important factors must be remembered when evaluating and using chemicals:

1. Chemicals will not clear stoppages or blockages in sewer mains. Be wary of any chemical that makes this claim. How does the chemical move 100, 200 or 300 feet down a plugged sewer to the stoppage at the proper concentration?

2. Laboratory or "desk top" demonstrations work because chemical concentrations are adequate for the amount of water involved. Apply these concentrations in the field and the volume of water in a sewer could require a large amount of costly chemicals to achieve the required concentration at the proper location. Ask your chemical supplier to calculate the exact amounts of chemicals needed to pro-

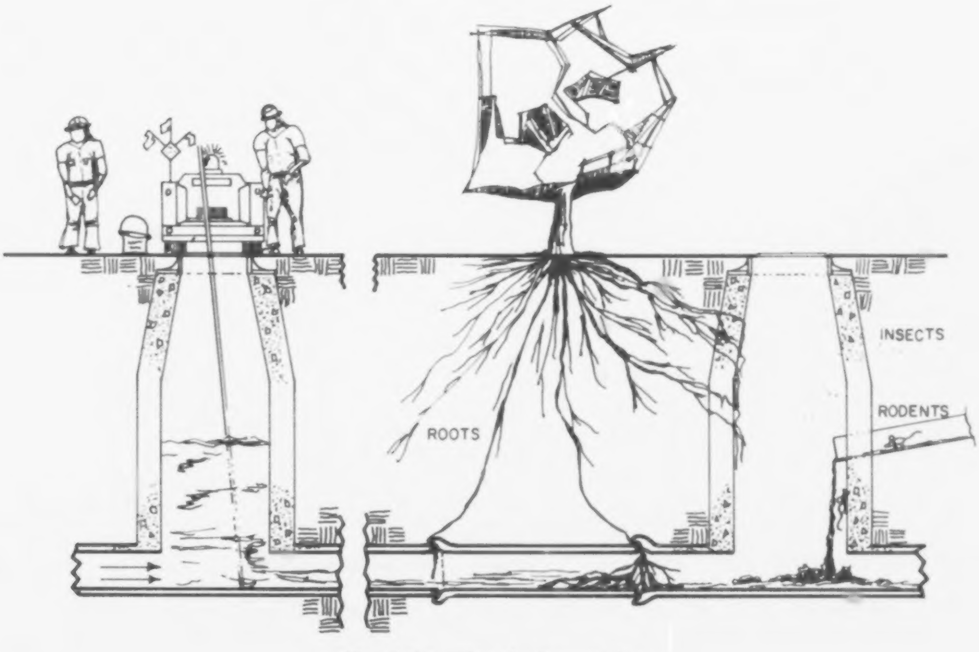


Fig. 6.34 Chemical operation

vide the desired chemical concentrations. For example, how much chemical is necessary to produce effective heat ranges in the sewer to dissolve grease or burn roots?

Don't get trapped into thinking you will at least be doing something if you buy a chemical. Very often you are merely contributing to the promoter's income, but not helping your situation. Contact water pollution control regulatory agency officials before using a chemical. Some chemicals are banned, while others are approved for appropriate use.

6.522 A Selection Procedure

Ideally chemicals you wish to use have been tested by a respectable laboratory and the results are favorable. Many universities, states, federal agencies and private testing laboratories conduct impartial tests of new chemicals before they are sold. For assistance and guidance regarding the application of chemicals to your particular problem, contact the U.S. Environmental Protection Agency, state water pollution control agencies and professional associations for recommendations. If a chemical has not been tested to your satisfaction, don't buy it.

All chemicals of the herbicide, insecticide, fungicide or rodenticide type require registration under the U.S. Environmental Protection Agency, Pesticides Regulation Division. These chemicals must have an approval number issued by EPA before use to prevent harmful contamination of a water course.

If a chemical does not require an EPA approval number and is untested, attempt to have a recognized laboratory perform the necessary tests. Otherwise, you must design your own testing program or risk throwing your agency's funds down the sewer.

WARNING

Never put any chemicals containing metal chips or filings into a sewer. This material will most likely settle out in the sewer without reacting or, if it does react, will produce hydrogen gas. Hydrogen gas increases the possibility of an explosive atmosphere developing in the sewer.

Here are some steps to follow if you must develop your own chemical testing program that are fair to your agency and the chemical company.

1. Ask the salesman to provide documentation of his claims in writing. Realize that he will only provide you with favorable results. A telephone call to the operator who used the chemicals will reveal if the chemicals are still being used successfully and if the costs are reasonable. Phone calls provide the opportunity for you to ask questions and also to obtain information people might be reluctant to put in writing.
2. Calculate the cost per foot of sewer to be treated before buying and applying the chemical. Costs may be too high even if the chemical works as claimed.
3. Work with the salesman to select a segment of sewer to serve as a test section (at least between two or more manholes). Develop a procedure for evaluating the effectiveness of the chemicals in the test section over a period of time recommended by the salesman. If the salesman refuses to demonstrate his product without charge and with an authoritative evaluation other than his own — *BE VERY CAUTIOUS.*
4. Take photographs or video tape the existing problems in a test section of sewer BEFORE the chemicals are applied.
5. Agree in writing with the salesman the results that should be produced by the chemicals and the method of payment for the chemicals. Determine payment on the basis of effectiveness of chemicals.
6. Apply chemicals as directed under the supervision of the salesman. Recalculate and verify dosage rates applied.
7. Retelevise and photograph or video tape the treated test section of sewer in accordance with your agreement with the salesman.
8. Be sure to keep good records before, during and after testing.
9. If the chemicals worked as claimed or agreed upon, pay the bill. If the chemicals did not work and there were no agreements regarding partial payments for partial effectiveness, then don't pay. No work, no pay.
10. Be wary of companies that offer a "money back guarantee." How do you get your money back if you are not satisfied? What happens if the company goes bankrupt? A reputable company with a good credit rating and bank references may be worth the risk.
11. Sometimes the selection of a "control" sewer may be helpful. No chemicals are applied to problems such as roots in this sewer. The purpose of this line is to provide a means of comparing problem development such as root growth in lines with and without chemicals.

If your agency is too small or without the resources to conduct an extensive testing and evaluation program as outlined in this section, try to use as many of the concepts discussed as possible to protect your agency.

Any company not willing to stand behind their products and subject them to an agreed upon evaluation, does not deserve to use your valuable time trying to sell you questionable products. When your agency has a firm policy regarding the testing of chemicals before purchase, the effectiveness of your chemical program will be greatly improved.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 357.

6.5A Chemicals can be used to control what types of problems in wastewater collection systems?

6.5B Why are some people reluctant to use chemicals to solve sewer problems?

6.5C Why might doing nothing be better than trying an untested chemical?

6.5D Why should metal chips or filings not be put into a sewer?

6.5E What precautions should be taken before developing a testing program?

6.53 Roots

6.531 Causes of Root Problems

Let's try to understand how to approach the cure for roots in your wastewater collection system by learning the causes of root problems.

One city in the United States had a serious problem. The residents were complaining about the high rate of stoppages in the wastewater collection system, the flooding of their homes, and the high costs they were having to pay to replace their home service lines.

The city council at one of their meetings discussed the complaints, heard the city manager tell of the high cost of keeping the flow within the pipe, and decided there was one simple answer to this problem — let a contract for the removal of all the trees in the rear easements (estimated cost of removal — $300,000) and pass an ordinance that would prohibit any replanting.

The next city council meeting was attended by almost the entire town. The public told the city council that they were not going to give up the shade in their side and rear yards. "There must be a way to keep our shade trees that have increased the value of our property and made our rear yards a beautiful place to enjoy and also to keep wastewater flowing in the collection system," commented one city resident. Somehow shade trees and wastewater collection systems sewers must be able to occupy the same easement.[7]

The remedy or cure for roots was not as simple as the city council had thought, or did they just try the most obvious and not try to seek the right cure for the problem of roots?

We are going to learn more about root control, but first we should try to understand the causes of root problems.

Let's think of the farmer of 1900 and some of the ways he combatted weeds in his field. He hoed and disced and some of the more progressive farmers were starting to treat the soil with chemicals that would control the weeds and allow the crops to flourish. Effective use of the proper chemicals on roots can help avoid a lot of hard work today.

Figure 6.35 shows roots hanging down from the top of a sewer pipe. This type of root growth is either new root intrusion or old root intrusion that has been pruned. If you have ever pruned a tree, you know that after each pruning the tree develops new growth just below each cut.

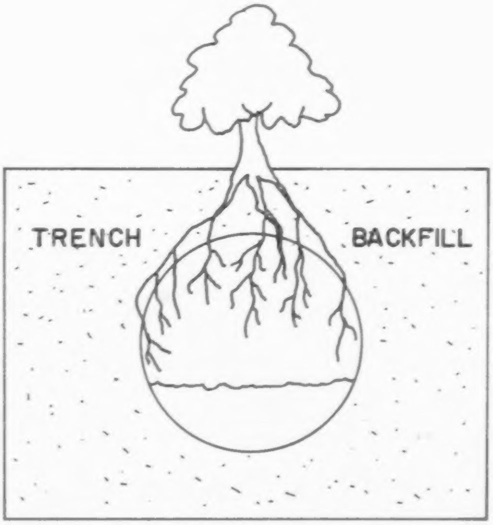


Fig. 6.35 Roots in a sewer pipe

What happens when roots are pruned or cut in a sewer line? The roots in the sewer line will grow similar to the limbs of a tree; thus after each pruning they will send out new growth just back from the cutting. Each time a root is cut, it will add new growth laterally, but also it will increase in diameter. When roots increase in diameter, serious problems develop that in time will break the pipe or open up the joint even more (Figure 6.36).

6.532 Information Needed From Vendor or Manufacturer

When you are starting a chemical program for root control, the following information must be obtained from the manufacturer:

1. Recommended herbicide or herbicides and EPA approval number. Verify information with EPA and other regulatory agencies because rulings sometimes change when new experience is gained.

---

[7] *Good planning might have placed the wastewater collection system in the street depending on distances, costs, and service requirements. This would not have prevented problems caused by roots, but would have placed the sewer lines a greater distance from trees planted in front yards than from trees in back yards if the sewer was in the back yard. Usually fewer trees are planted in front yards than back yards.*

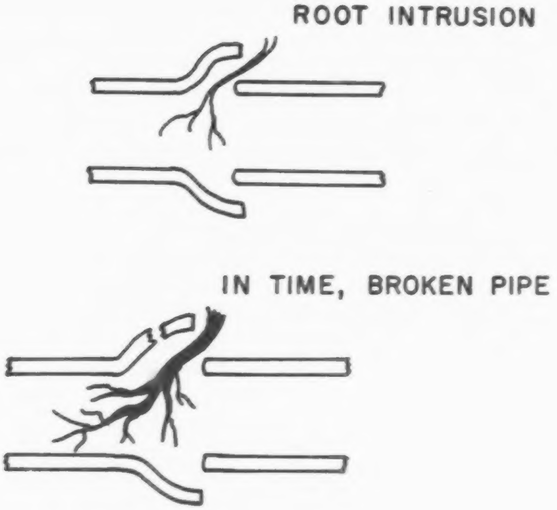


Fig. 6.36 Root breaking pipe

2. Recommended method of application such as flooding, spraying or foam. Sometimes the application of a combination of two herbicides is more effective than only one herbicide.
3. Concentration of chemical and amount required to treat a selected sewer line. Also learn the correct way of determining the specified concentration for other sizes and lengths of sewers for future reference.
4. Time of contact of chemical with roots, or time required for the sewer to be flooded or blocked with chemical to achieve root kill.
5. Preferred meteorological conditions at time of application. Rates of herbicide uptake through roots are largely determined by rates of plant transpiration or water loss from the leaves of the plant.
6. Cost for chemicals and application, including labor and equipment.
7. Hazards to wastewater collection system operators working downstream from section where chemicals will be applied.
8. Effects upon the downstream wastewater treatment plant by the use of the chemical.
9. Effects on receiving waters of wastewater treatment plant effluent.
10. Material Safety Data Sheet (MSDS).

6.533 Application (flooding, spraying and foaming)

This is the area where many chemicals fail to perform to the manufacturer's claims and make many maintenance people leery of new chemical products. If specific claims are made as to results to be expected, then the chemical manufacturer should be willing and able to provide *SPECIFIC* instructions as to method of application, concentration of chemical, and required contact time. Directions for the application of some chemicals suggest that you "dump one can of chemicals in the sewer and if that doesn't work, dump in another can." Haphazard instructions of this type will usually produce haphazard results.

To apply a chemical to control roots, first televise the section to be treated to determine existing conditions. When ready to apply the chemicals, isolate the system to be treated by plugging the upper and lower ends of the sewer line to be treated (usually a segment of line between manholes). Mix the chemicals according to manufacturer's directions and safety precautions, and slowly meter the chemicals into the test section of line. If the line is to be flooded, allow the mixture of water and chemical to fill the sewer and manhole to a level three to six inches above the top of the sewer pipe in the upstream manhole. Leave the line plugged and the chemicals in the line for the specified contact time. Maintain constant observation of the system above the plug to prevent flooding of a home or business. Flooding sewers to treat roots can only be done in low flow sewers. Otherwise, a by-pass pumping and piping system may have to be devised and installed.

One method of reducing chemical cost is to reuse the chemicals in downstream sections of the sewer. Plug the lower sections of the line and allow the chemicals to flow downstream to the next section of line requiring treatment.

A small addition of chemicals may be necessary to maintain the desired concentration. Some dilution of the original chemical batch usually occurs when the chemical slug flows down to the next test section.

Another method of recycling used chemicals is to pump the chemicals from the test section into a tank and reapply them in another section. Some additional chemicals may have to be added to maintain the desired dosage in the next test section. Depending on the chemical used, be sure to follow manufacturer's recommendations regarding safe handling of chemicals at all times.

Infiltration of water into the sewer line may be expected to wash the chemicals off the roots and decrease the effectiveness of root kills. Treatment of roots during periods when infiltration rates are low usually is more effective.

6.534 Evaluation

Root control by chemicals is not as fast as removing roots by cutting them off with a power rodder, but chemical control is more permanent. Effective chemicals can control roots in a sewer for as long as two to five years.

To evaluate the effectiveness of a chemical root control program, televise test and control sections one week, one month and three months after treatment to evaluate the effectiveness of the chemicals. With proper chemicals and application, root control by the use of effective chemicals is a very desirable preventive maintenance program and is cost effective.

6.535 Safety Precautions

Before using any chemicals make sure the field crew has thoroughly read the label on the chemical container and understands the type of chemical, reactions that will occur, safety measures for handling and applying, equipment used for mixing and application, action to be taken if the chemical is spilled or splashed on operators or materials, and clean up. Action in case of an accident includes first aid treatment to be given and how to inform a doctor of the exact chemical compounds involved if a person needs medical aid so the doctor will know how to neutralize the chemical and properly treat the victim.

When handling or mixing any chemical, always wear rubber gloves, an apron, goggles or a face mask for protection. Do not enter manholes without proper precautions (Chapter 4, Section 4.3, Routing Traffic, and Section 4.4, Manhole Hazards). Spillage of root control chemicals on lawns or gardens will kill plants and sterilize soil for long periods of time.

WARNING

1. Do not mix unknown chemicals.
2. Do not add a strong acid or alkali (base) to a chemical unless instructed to mix the chemicals.

6.536 Other Methods of Root Control

This section has emphasized the control of roots in sewers by the use of chemicals. There are other methods of root control.

First, the best way to control roots is to install sewers that don't leak. Modern pipe materials and joints can be installed without leaks so roots can't enter a sewer. In older sewers where there is the potential for root intrusion, methods of root control include:

1. Eliminating deep rooted trees.
2. Inserting a liner in the sewer (Chapter 10, Sewer Rehabilitation).
3. Not allowing trees to be planted over sewers.
4. Removing roots and sealing sewer (Chapter 7, Section 7.6, Sealing Grout).
5. Frequent clearing of roots from sewer.

Another possible approach to killing roots in sewers is by the use of scalding hot water. Roots can be thermally killed in sewers by flooding one manhole section at a time with scalding hot (82° to 98°C or 180° to 210°F) water for 30 minutes. A truck-mounted packaged steam generator is required. The advantages of this system include a good root kill at any time of the year, the killing of rodents and insects, and the liquifying of grease. Limitations of this approach include high energy costs and the problem of handling or disposing of the liquified grease.

6.537 Additional Reading

An excellent paper on the evaluation of chemicals for root control is "Chemical Control of Tree Roots in Sewer Lines," by John F. Ahrens, Oliver A. Leonard, and Neal R. Townley in Journal of Water Pollution Control Federation, Volume 42, Number 9, pp. 1643-1655 (September 1970). Also see "Thermal Kill of Roots in Sanitary Sewers," by James T. Conklin, Deeds & Data, Water Pollution Control Federation, February 1977, p. 4.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 357.

6.5F What happens when roots in a sewer are cut?

6.5G What information must be obtained from the manufacturer before starting a chemical program for root control?

6.5H How can chemicals be applied for root control?

6.5I How can homes or businesses become flooded during a chemical operation?

6.5J How can chemicals used for root control be recovered and recycled?

6.5K What safety precautions should be used when chemically treating roots?

6.54 Grease

Grease and soap problems used to be confined to sewer lines that served restaurants or industrial dischargers. These materials were controlled to some degree by grease traps or grease interceptors. With the widespread use of home garbage disposal units, the problem has now spread throughout the collection system.

Problems commonly develop when greases, oils and soaps cool and solidify and form a coating or deposit on the walls of a sewer. The rate of build up of a grease deposit depends on the amount of grease carried by the wastewater, the flow and velocity of the wastewater, and the size of the sewer. If the sewer changes slopes (steep to flat), intersects with another sewer, or has dips or other alignment irregularities, then these factors can encourage the development of grease deposits. Sewers larger than 18 inches in diameter tend to have fewer grease problems than smaller sewers because they usually flow more than half full with velocities high enough to prevent the build up of grease.

Most uniform building codes or sewer-use ordinances require commercial and industrial dischargers to install grease traps or grease interceptors if grease is in their wastewater discharges. These units are similar to a septic tank and are designed to allow floatables (greases, oils and soaps) to accumulate on the surface and heavy solids to settle to the bottom. The floatables and solids must be removed on a regular basis.

Responsibility for cleaning and maintaining grease traps and grease interceptors depends on community policy, but usually it is the responsibility of the discharger. Unfortunately many dischargers do not know how to or do not bother to properly clean and maintain grease traps and grease interceptors. Some industries do an excellent job because contents of the traps can reveal that problems have developed in their industrial processes that are causing a loss of profits and also causing an increased sewer-use billing.

Grease traps and interceptors must be thoroughly cleaned. Merely pumping the liquid out of the trap or interceptor does not remove the grease or solids. Frequency of cleaning may vary from twice a month to once every six months, depending on the amount of grease in the wastewater and flow conditions.

Field evaluations of grease traps and grease interceptors have revealed that usually they are undesirable and ineffective for the following reasons:

1. Dischargers (such as restaurants) do not properly clean and maintain the facilities.
2. In spite of the installation and maintenance of the facilities, grease problems still develop in smaller sewers. Problems develop because the facility is too small, improperly maintained, or the wastewater temperature was so high that the grease did not solidify until it reached the sewer.
3. Undesirable side effects are produced by grease traps and interceptors in the collection system and the wastewater treatment plant.
    a. Solids deposited on the bottom of the trap or interceptor start to decompose. This decomposition produces odors in the collection system, exerts a greater load on the wastewater treatment plant, and increases the sewer-use charges.
    b. Decomposing material from the trap or interceptor can flow into the wastewater collection system and increase the production of hydrogen sulfide (see Section 6.6, Hydrogen Sulfide Control).
    c. When the trap or interceptor is cleaned, a large mass of undesirable material must be disposed of in a sanitary landfill.

In summary, we may be better off without grease traps and grease interceptors, because without them grease gets into the sewer where collection system operators have the knowledge and equipment to handle grease problems better than anyone else. The ultimate solution to grease problems is to educate the sewer users that grease, oil, fat and soap should not be discharged into the sewer. These materials should be separated, salvaged and recycled if possible like aluminum cans and waste papers.

Effective grease and soap control with methods available to the collection system maintenance operator include the high velocity cleaner, hydraulic balling, power rodding and bacteria cultures. Many chemicals have been sold in the past and are being sold today to control grease and soap in sewers. These chemicals are sold as bio-acids, digesters, enzymes, bacteria cultures, catalysts, caustics, hydroxides and neutralizers. Many of the compounds are claimed to control odors, remove grease, eliminate roots and accelerate activity in biologial treatment processes in treatment plants. By scanning any trade journal, you can easily develop an extensive list of these products. Many have their proper use in specific locations under specified conditions.

CAREFUL EVALUATION OF THE RESULTS PRODUCED BY THESE CHEMICALS AND BACTERIA CULTURES SHOULD BE MADE IN COMPARISON WITH MECHANICAL AND HYDRAULIC CLEANING METHODS USED FOR SEWER LINE MAINTENANCE. The ideal control of many troublesome materials is at the source by educating the public that grease, oils, coffee grounds and eggshells should be disposed of in the garbage can along with paper, tin cans and plastic containers. This practice would eliminate some of the homeowners' plumbing problems and make the job of the collection system and treatment plant operators much easier. The only recommendation we offer regarding these types of chemicals is to develop a stringent evaluation program to test these products as outlined in Section 6.522.

6.55 Odors

Odors have long been associated with collection systems and wastewater treatment plants and are primarily caused by the production of hydrogen sulfide (Section 6.6, Hydrogen Sulfide Control). Some industrial dischargers produce offensive odors that are not caused by hydrogen sulfide. Since the control of hydrogen sulfide is presented in Section 6.6, this section will emphasize overall odor control.

Most odors can be controlled in a properly designed, cleaned and maintained collection system. Odor problems usually are due to low velocity flows, long transmission times in the collection system, high temperatures and poorly maintained collection systems. If these problems can be corrected, odor problems would be eliminated. Odor control is usually obtained by controlling the production of hydrogen sulfide (Section 6.6). Masking agents are used to mask or overpower an undesirable odor. They do not control the production of undesirable odors. In some cases a combination of both odor control and masking agents are used to combat odor problems.

One of the most common causes of odors results when the air flow in the sewer above the flowing wastewater is stopped at a siphon or by a small sewer joining a large sewer so low that an air seal is produced. These problems can generally be cured with air lines or air jumpers. These lines are pipes that take air off the top of the inlet structure and return it at the end of the siphon.[8] Wet wells are seldom the site of substantial sulfide generation, even though they are often the place where odors are released from wastewater. An air line or air bypass around the lift station can be used to control odors released from a wet well if the force main is not too long.[9]

6.551 Masking Agents

There are numerous masking agents available on the market which generally consist of a water base and an oil carrier of perfume scents to overpower or mask the objectionable odor. Instead of the sewer smelling like rotten eggs, you can now have your choice of mint, pine, banana, channel #32, or an assortment of other aromas to mask sewer odors.

---

[8] *See DESIGN AND CONSTRUCTION OF SANITY AND STORM SEWERS, MOP 9, Water Pollution Control Federation, 601 Wythe Street, Alexandria, Virginia 22314. Price $17.00 to members; $21.50 to others. Indicate member association when ordering.*

[9] *See PROCESS DESIGN MANUAL FOR SULFIDE CONTROL IN SANITARY SEWERAGE SYSTEMS, page 6-8 to 6-10, Technology Transfer, U.S. Environmental Protection Agency, Center for Environmental Research Information (CERI), 26 West St. Clair Street, Cincinnati, Ohio, 45268, October 1974.*

Obviously a masking agent does not correct the cause of the odor problem. If the original problem is caused by hydrogen sulfide, you still have the other problems created by high concentrations of hydrogen sulfide that include a poisonous or toxic gas that is flammable and explosive. Also hydrogen sulfide can be converted to sulfuric acid which is very corrosive. Therefore you haven't accomplished anything except to hide a potentially hazardous situation. Probably every agency in the country has used masking agents for the control of odors to satisfy a complaining citizen, but they have not corrected the source of the problem.

6.552 Information Needed from Manufacturer

Use of a masking agent requires the following information:

1. Recommended deodorant or masking agent.
2. Method of application — drip feed, spray, atomizers or blowers.
3. Feed rates and amount of masking agent required to meet feed rates. Time of application, such as late afternoon and early evening, or periods of maximum odor production.
4. Cost of masking agent.
5. Effect upon wastewater treatment plants with biological treatment processes.
6. Effect upon waters receiving effluent from treatment plant.
7. Safety precautions for operators. Any restrictions on use, especially in residential areas.

6.553 Application of Masking Agents

Manufacturer's procedures must be followed exactly to achieve desired effectiveness. Excessive use of any chemical is discouraged because this practice is the same as throwing money down the sewer. Application may be simply removing the masking agent from a one to 55-gallon container using a hose and needle valve. Allow the masking agent to drip into a manhole or lift station wet well at a rate of so many drops per minute. More elaborate equipment and procedures include the use of timers, blowers, atomizers and specially designed nozzles.

6.554 Evaluation

Very careful consideration must be given to these applications because the masking agent is quite expensive. Use may be justified for short time periods until the cause of the problem can be corrected. Remember, masking agents do not eliminate or correct the source of the problem.

6.555 Measurement of Odors

To evaluate the effectiveness of an odor control program, gas detection equipment is available. The U.S. Bureau of Mines approves equipment capable of measuring the concentrations of both ammonia and hydrogen sulfide in parts per million.

6.56 Corrosion

Control of corrosion is discussed extensively in Section 6.6, Hydrogen Sulfide Control. Use of chemicals to control hydrogen sulfide generation is contained in Section 6.66, Hydrogen Sulfide Control Using Chemicals.

6.57 Rodents and Insects

Some collection systems are infested with rodents and insects. Rats are a serious problem in some areas because of the threat to public health and the destruction of food. Effective control of this problem requires assistance from the local health department or animal control agency for the development and implementation of a cooperative eradication program. These agencies can establish a vector (a bug, insect, fly or rodent that can transmit infection) control program and can recommend types of poisons and when and where they should be distributed. Tight sewers with proper traps and connections and good manholes can limit rodent problems.

Insect control can be achieved by an effective maintenance program of flushing slow or stagnant lines periodically during the warm summer months or whenever insects from sewers are a problem. A serious insect problem can be caused by small flies that breed and live in trickling filters and sewers. Cooperation with the local health department can expedite an effective control program.

Control of insects in manholes is best achieved by an effective maintenance program that keeps manholes clean. Use of water to wash and flush manholes can keep them clean. Spraying manholes with an insecticide for dangerous insects and washing down the manhole are good practices if insects are a problem.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 357.

6.5L What are the causes or sources of grease problems?

6.5M How can odors be controlled from a wastewater collection system?

6.5N What are two serious shortcomings of the use of masking agents to overcome odors?

6.5O Why should insects and rodents in a wastewater collection system be controlled?

6.6 HYDROGEN SULFIDE CONTROL

by William F. Garber

6.61 Why Control Hydrogen Sulfide?

Hydrogen sulfide (H_2S) is one of the most serious problems confronting wastewater collection system operators. The hotter the weather, the flatter the sewers and the longer the flow time to the wastewater treatment plant, the worse the problem becomes. Some of the problems created by hydrogen sulfide include:

1. Paralysis of the respiratory center and death of operators,
2. Rotten egg odors,
3. Corrosion and possible collapse of sewers, structures and equipment,
4. Loss of capacity of sewer, and
5. A flammable and explosive gas under certain circumstances.

6.62 How is Hydrogen Sulfide Produced?

The major portion of the sulfide content in wastewater arises from the conversion of sulfate (SO_4^{2-}) to sulfide (S^{2-}) by bacteria in the slime in sewers. Materials containing proteins in the wastes are an equally important food for bacteria that produce hydrogen sulfide. Any sulfur containing compound that is available as a food for slimes that reduces oxygen in the wastewater can produce odorous, reduced sulfur compounds, including hydrogen sulfide.

The relationship between hydrogen sulfide (H_2S) and the sulfide ion (S^{2-}) in wastewater is tremendously sensitive to pH. The lower the pH, the more hydrogen sulfide is present as compared to sulfide. Therefore in terms of odor and corrosion control, low pH values in wastewater are most undesirable.

Hydrogen sulfide is not only odorous, but upon escape to the sewer walls can be converted to sulfuric acid by other bacteria. In some cases, solutions of sulfuric acid in excess of 40 percent have been found on walls of the sewer. Where such heavy acid concentrations develop, washing of such areas once a day by such action as rising wastewater flows does not appear to be sufficient to prevent corrosion.

Another important aspect of the establishment of low pH values in a wastewater actively generating sulfide such as has occurred under slug discharges of acids, is the fact that a low pH can result in the swift establishment of a toxic atmosphere. Deaths have occurred as a result of such conditions. Remember that H_2S is about equivalent in toxicity to hydrogen cyanide. Levels of hydrogen sulfide toxicity are as follows:[10]

1. 10 ppm for 8 hours, not dangerous but will produce headache and irritation of eyes and nose.

10 PPM FOR 8 HOURS

2. 50 ppm for 8 hours, severe symptoms of poisoning.
3. 300 ppm, minimum concentration known to have caused death.
4. 3000 ppm, quickly fatal.

The ppm concentration of hydrogen sulfide in the sewer atmosphere is quite different from that in the wastewater. A concentration of 1 mg/*L* (ppm) in turbulent wastewater can quickly produce a concentration of 300 ppm in an unventilated atmospheric space. The tabulation above shows that this concentration may cause death.

In a sewer or waste channel flowing partially full, there will almost always be some oxygen present in the air space above the flowing wastewater. However, sulfide forms and is present in the flowing wastewater. *ANAEROBIC*[11] reactions produce sulfide in the slimes while sulfide oxidation is occurring in the surface of the flow. The net sulfide present represents the difference between the amount produced and the amount oxidized.

a. In general, the faster and more turbulent the flow, the more oxygen is dissolved, and thus the more sulfide is oxidized to sulfate (SO_4^{2-}). However, manhole turbulence and ventilation often cause corrosion damage in areas immediately downstream from a manhole.

b. Conversely the more sewer slimes arising from more wetted walls, from heavy sand and debris in the bottom and from slower flows, the higher the residual sulfide concentration.

6.63 Control of Hydrogen Sulfide

Design, using our knowledge about sulfide generation, can, in many cases, accomplish the control of sulfide release and thus control much of the odor and corrosion. Designers must realize that the higher the wastewater temperature, the greater the production of hydrogen sulfide. Thus designs acceptable in cooler climates may be unacceptable in warmer climates.

Another factor of importance in terms of maintenance is the presence of slimes in sewers. Sulfate is split by bacteria living in the sewer slimes, and the more area or habitat for such slimes, the more sulfide produced and the greater the odor, corrosion, and maintenance problems. The cleaner the sewers the fewer the slime bacteria and the smaller the problems caused by sulfide.

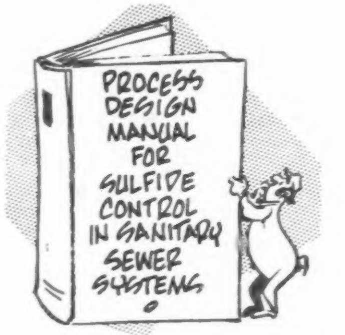
Generally speaking, there are only two positive methods of hydrogen sulfide control. These are:

---

[10] *California Division of Industrial Safety Orders, Title 8, Section 4.32. Gas concentrations are given in parts per million parts (ppm) by volume.*

[11] *Anaerobic (AN-air-O-bick). A condition in which "free" or dissolved oxygen is NOT present in the aquatic (water) environment. If dissolved oxygen is present, aerobic conditions exist.*

1. Design according to the relationship outlined by Dr. Pomeroy (footnote[12]) so that sulfide release will be minimized, and



2. Use of construction materials that the sulfuric acid will not attack. Odor is still a problem and positive methods of odor control are required.

If design can be close to the conditions required by the Pomeroy relationships, careful and routine sewer cleaning must be carried out. Excess sand and grit in the sewers not only use up sewer capacity, but slow velocities and provide more slime concentrations for the generation of sulfide. Wastes with strengths *(BOD)*[13] or temperatures greater than design also can cause corrosion and odors in spite of the use of this design method as will factors such as turbulence at joints and wash-off of corrosion products. In cases where industrial wastes with high BOD and temperatures are encountered, a sewer-use ordinance should be enforced to control these discharges. However, its use should be considered in every installation since it would help minimize both corrosion and odor control.

Provision of materials of construction which will be unaffected by the sulfuric acid resulting from sulfide release is an obvious answer to the corrosion problem. Clay pipe, plastic pipe, the lining of reinforced concrete pipe and structures with materials such as PVC, furane, coal tar epoxy and stainless steel, epoxy lined asbestos-cement pipe, and corrugated steel pipe with asphalt and asbestos linings are materials which have been proposed and/or are offered for this purpose. Clay pipe and reinforced concrete pipe lined with PVC sheets keyed to the concrete are the only materials with a use record long enough at this time to give reliable data for design use. The PVC lining is subject to damage from hard materials floating in the sewer. Where corrosion will occur over some predictable period, sacrificial lining of pipes with high calcium carbonate mortars is used. The entire pipe also can be made using limestone sand and aggregate and high calcium carbonate mortars. Comparative tests have shown that pipe made entirely with limestone aggregate will last 3 to 5 times longer than pipe made with ordinary concrete.

Provision of corrosion resistance still leaves the problem of odor control. Where design cannot provide for the natural oxidation of sulfide and corrosion resistant materials of construction are necessary, carefully designed odor control facilities must be installed. Odor control at treatment plant wet wells may be achieved by withdrawing odorous air and passing it up through trickling filters or bubbling it up through aeration tanks in activated sludge plants. This odorous air is moist and often causes corrosion problems in the transmission ducts.

In addition, methods such as activated carbon towers and packed absorption towers have been successfully used for such odorous air. Masking has been used as an interim solution for acute odor problems. Treatment of the exhausted odors is complicated by the fact that the gas is made up of stench materials and solvents. Removal of both major components is necessary.

Compressed air has been successfully injected into force mains by some operators to control problems caused by hydrogen sulfide. This approach is simple and effective in many, but not all situations. Turbulent conditions are critical to dissolve oxygen in the air into the wastewater to successfully prevent sulfide buildup and to oxidize sulfide already present in the wastewater.[14] Aeration of wastewater in lift station wet wells is helpful to keep *SEPTIC*[15] conditions and production of hydrogen sulfide to a minimum. The procedure is especially effective during low flow periods. Be very careful with aeration in a wet well that you do not cause pump cavitation and pumps to become air bound.

Chemical treatment (Section 6.65) of the wastewater is used to control hydrogen sulfide. Chemicals are expensive, but can be effective over a short time period. Zinc and iron salts precipitate the sulfide. Lime dosage at about 8,000 mg/*L* over an hour will kill the slimes over periods of one day to about two weeks, depending upon conditions. Use of lime can produce large quantities of lime sludge which can cause disposal problems. Other materials providing a pH greater than about 11 or 12 over a half an hour can be used instead of lime. Chlorination with chlorine or hypochlorite is effective, but expensive. Neutralization of the sulfuric acid on the sewer walls by lime dusting or ammonia release has been used. The process is expensive and results have been variable.

AS A GENERAL SUMMARY, HOWEVER, CHEMICAL TREATMENT CANNOT BE CONSIDERED TO BE A PERMANENT ANSWER FOR MOST LOCATIONS. IT PROVIDES RELIEF UNDER ACUTE CONDITIONS, BUT IS GENERALLY TOO EXPENSIVE FOR CONTINUOUS USE.

The collection system operator must urge that engineers consider the available theory in original design and then, themselves, strive to keep the facilities as close to the design conditions as is possible by use of as logical and as frequent a cleaning schedule as is feasible and the control of waste materials discharged to the collection system. Where this is not possible, resistant materials of construction, odor treatment and chemical dosage in acute situations may be necessary. The maintenance operator's options are limited, but knowledge of the possible causes of trouble and of the available solutions enable the operator to make the most logical use of available forces and procedures.

---

[12] *U.S. Environmental Protection Agency, Center for Environmental Research Information (CERI), 26 West St. Clair Street, Cincinnati, Ohio, 45268, October, 1974.*

[13] *BOD (BEE-OH-DEE). Biochemical Oxygen Demand. The rate at which microorganisms use the oxygen in water or wastewater while stabilizing decomposable organic matter under aerobic conditions. In decomposition, organic matter serves as food for the microorganisms and energy results from the oxidation of the food.*

[14] *For details on the design of systems to inject compressed air into force mains, see PROCESS DESIGN MANUAL FOR SULFIDE CONTROL IN SANITARY SEWERAGE SYSTEMS, pages 5-1 to 5-9, Technology Transfer, U.S. Environmental Protection Agency, Center for Environmental Research Information (CERI), 26 West St. Clair Street, Cincinnati, Ohio, 45268, October, 1974.*

[15] *Septic (SEP-tic). This condition is produced by anaerobic bacteria. If severe, the wastewater turns black, giving off foul odors, contains little or no dissolved oxygen and creates a heavy oxygen demand.*

Lawrence[16] forcefully pointed out that sewer maintenance problems vary with location and thus in terms of wastewater temperature, strength, and age as well as design factors. His paper summarizes in considerable detail the factors of importance and which portions of the country are particularly susceptible to maintenance problems.

6.64 Collection System Maintenance and the Treatment Plant

Sewer maintenance and sewer design have a definite and important effect upon wastewater treatment. This is particularly true of the south and southwest and where separate sewers with long flow times are constructed. However, with the mandated implementation of secondary treatment throughout the nation, this factor should be examined by everyone. Table 6.3 is an example of *DEGRADATION*[17] in the wastewater which did occur in a wastewater collection system and did have a substantial effect upon treatment plant operations. It also shows that such degradation can be measured by either the oxidation reduction potential (ORP) or the dissolved sulfide content.

TABLE 6.3
DISTANCE TO TREATMENT PLANT vs. DISSOLVED SULFIDE, mg/L
(EFFECTIVE BOD 304 MG/LITER)

Distance Upstream, of Treatment Plant, Miles	ORP, E_H* in MV	Dissolved Sulfide, mg/liter
9	+ 258	0.2
6	+ 122	0.6
5	+ 70	1.1
3	+ 50	1.2
0	+ 48	1.8

*E_H is the potential required to transfer electrons from the oxidant to the reductant in millivolts, MV.

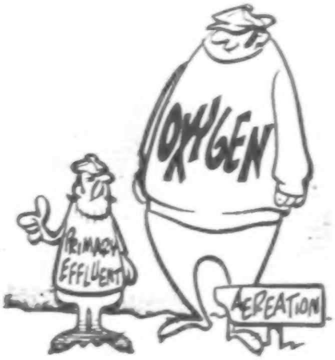
Obviously by keeping deposits and slimes to a minimum and flow velocities high enough, sewer maintenance can affect the degradation of wastewater. Sewer design is, of course, very important (Chapter 3), but collection system operators must try to make what is available produce the best possible results.

Degradation of the wastewaters in the collection system produces several undesirable impacts at a wastewater treatment plant:

1. Odor and corrosion problems in plant facilities, and
2. Initial or immediate oxygen demand on biological treatment processes.

The effect of low ORP and high dissolved sulfide content upon odor and corrosion is evident.

The initial oxygen demand at the start of a biological treatment process may arise in most part from the septic condition of wastewater arriving at the treatment plant. At Los Angeles the initial oxygen demand is in the order of 50 mg/*L*-hour. This means that a substantial amount of oxygen must be available at the moment the primary effluent reaches the aeration basins in order to reestablish *AEROBIC*[18] conditions and to reduce problems from the release of odors.



QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 357.

6.6A What problems are created by the presence of hydrogen sulfide?

6.6B What are the sources of hydrogen sulfide in sewers?

6.6C List the factors that you consider important in the production of hydrogen sulfide.

6.6D How does collection system maintenance affect the wastewater treatment plant?

6.65 Chemical Control of Hydrogen Sulfide

In the preceding pages you have learned that hydrogen sulfide (H_2S) is toxic, can cause corrosion, and in high concentrations is flammable and explosive under certain conditions. Hydrogen sulfide is produced by sulfur reducing anaerobic organisms that can thrive in a wastewater collection system. These sulfur reducing organisms require the following environment to thrive:

1. The absence of dissolved oxygen (DO) in the wastewater.

---

[16] Lawrence, C.H., "Sewer Corrosion Potential," Journal Water Pollution Control Federation, Volume 37, 1067-1091, August 1965.

[17] *Degradation (de-grah-DAY-shun). The conversion of a substance to simpler compounds. For example, the degradation of organic matter to carbon dioxide and water.*

[18] *Aerobic (AIR-O-bick). A condition in which "free" or dissolved oxygen is present in the aquatic (water) environment. If no dissolved oxygen is present, anaerobic conditions exist.*

2. The presence of sulfate or sulfur compounds. These compounds are present in most wastewaters or are produced by the degradation of materials containing proteins.
3. The greater the strength (higher BOD) of the wastewater, the greater the rate of sulfide generation.
4. The warmer the temperature of the wastewater, the more favorable the environment.
5. The slower the flow velocity and the dirtier (more debris in) the sewer, the better the conditions for hydrogen sulfide generation.

Chemical control of hydrogen sulfide generation may consist of use of one of the six chemicals listed below in order of popularity of application:

1. Chlorine (Cl_2)
2. Hydrogen peroxide (H_2O_2)
3. Pure oxygen (O_2)
4. Air
5. Lime ($Ca(OH)_2$)
6. Sodium hydroxide (NaOH)

6.651 Chlorine (Cl_2)

The most widely used chemical for hydrogen sulfide control has been chlorine injected into the wastewater flow at various points along the collection system. Sewer lift stations often serve as injection sites due to the availability of the site and the required utilities such as water and power to operate the chlorination equipment.

Chlorine doses of 10 to 20 mg/*L* have been effective in controlling the production of hydrogen sulfide in many collection systems. Doses of chlorine at these levels are toxic to most organisms in the wastewater. When these aerobic organisms are inactivated or killed, they no longer require oxygen or exert a BOD. This permits the wastewater to remain aerobic longer and delays the start of anaerobic decomposition which produces sulfide. Chlorine also is toxic to the organisms that convert sulfate to sulfide.

Chlorination may be accomplished by the use of chlorine gas and chlorinators or by the addition of a hypochlorite solution. Hypochlorite is available as a dry powder, in tablet form, or as a liquid usually as sodium hypochlorite.

When considering the chlorination of a wastewater collection system, beware of the following problems:

1. Chlorine is a highly toxic, oxidizing chemical. Leaving this chemical unattended in or adjacent to residential areas with the constant possibility of leaks may result in serious injury to the public and to private property.
2. Chlorine requires application equipment including evaporators (if use rates are high), chlorinators, injectors, solution diffusers in the sewer line, and possibly an air gap water system with separate injector water pumps. All of this equipment must be properly maintained.
3. For effective results, the chlorine solution must be added at a point of high turbulence where it mixes instantly with the wastewater flow.
4. Under extremely low flow conditions or if the solution diffuser is improperly designed, chlorine could be released from the diffuser and cause serious damage to the chlorination equipment.
5. If chlorine dosage is to be properly controlled to meet collection system sulfide generation rates or daily variation of flows, then flow metering and chlorine feed control equipment will be required.
6. Chlorine costs are increasing rapidly. Large amounts of energy are required to produce chlorine. If a chlorine shortage occurs, chlorine may not be available for hydrogen sulfide control in collection systems.
7. NEVER apply an overdose of chlorine near a wastewater treatment plant. Chlorine is toxic to organisms and can kill aerobic organisms in secondary biological treatment processes.

CHLORINE SAFETY

Any person using chlorine should be thoroughly trained by the chlorine supplier in safe procedures for storing and handling chlorine. Operators must receive instruction in the use of self-contained breathing apparatus and the use of chlorine container repair kits.

For additional information on chlorine safety, read:

1. *CHLORINE MANUAL* (4th Edition), The Chlorine Institute, Inc., 2001 L Street, NW, Suite 506, Washington, D.C. 20036. Price, $10.00.
2. *CHLORINE SAFE HANDLING,* Chlor-Alkali Business Unit, Chemical Division, PPG Industries, Inc., One Gateway Center, Pittsburgh, Pennsylvania, 15222.

6.652 Hydrogen Peroxide (H_2O_2)

Hydrogen peroxide was first used in the wastewater field for providing additional oxygen (O_2) to the activated sludge process in wastewater treatment plants. Hydrogen peroxide has been found beneficial in collection systems for hydrogen sulfide and odor control. Wastewater can be kept aerobic by the application of large amounts of hydrogen peroxide.

The hydrogen peroxide you buy in the drugstore for medical purposes has a strength of 3 percent, while the hydrogen peroxide used in a collection system may have a strength from 35 to 50 percent.

APPLICATION OF HYDROGEN PEROXIDE

Your hydrogen peroxide supplier should be very helpful in establishing your application program. Control of hydrogen sulfide using hydrogen peroxide relies on two major factors:

1. Conditioning Program. To inactivate and control slimes, dose with sodium hydroxide ($Na(OH)$) or calcium hydroxide ($Ca(OH)_2$). Lime ($Ca(OH)_2$) dosage at about 8,000 mg/*L* over an hour will kill the slimes over periods of one day to about two weeks, depending on conditions. However, disposal of lime sludge must be considered. Slimes are not affected by reasonable doses of hydrogen peroxide. Slimes should be controlled before the beginning of the application of hydrogen peroxide. Periodically the slimes may have to be controlled during the regular hydrogen peroxide application program.
2. Application Program. Effective control of hydrogen sulfide by hydrogen peroxide requires the feeding of sufficient hydrogen peroxide during the daily variation of flows to be sure sufficient amounts of hydrogen peroxide are fed to the wastewater to neutralize the hydrogen sulfide and maintain aerobic conditions. Unlike chlorine, excessive hydrogen peroxide is not detrimental to the wastewater treatment

plant. However, excessive dosage of any chemical is throwing money down the sewer.

Recommended doses:

Hydrogen Peroxide Concentration, %	Dose Rate, mg/*L* H_2O_2 per mg/*L* of total H_2S
35	13 to 15 mg/*L*
50	11 to 13 mg/*L*

Occasionally repeat the preconditioning dosage of sodium hydroxide or calcium hydroxide (lime) to control slime growth.

The actual method of applying hydrogen peroxide will be recommended by the supplier. Usually either a drip feed or pumping system is used and neither system is as expensive to install or as complex as a chlorination system.

Hydrogen peroxide, like chlorine, has the following disadvantages:

1. Must be isolated and protected from access by the public, especially children.
2. Is very corrosive and must not be contaminated by foreign material.
3. Containers must be protected from the sun to prevent heat build up.

HYDROGEN PEROXIDE

HYDROGEN PEROXIDE SAFETY

1. Follow manufacturer's directions carefully.
2. Wear goggles and rubber gloves. Hydrogen peroxide must not come in contact with skin or eyes.
3. Avoid getting hydrogen peroxide on your clothing or shoes and especially combustible materials because drying may cause a fire.
4. In case of a spill or a fire, use *WATER ONLY* to dilute the hydrogen peroxide or put out the fire.
5. Keep flames, open lights, and sparks away from hydrogen peroxide containers and the application system.

6.653 Pure Oxygen (O_2)

With the great thrust to clean up the environment and the desire to control water pollution, many new treatment plants are using pure oxygen activated sludge systems. Pure oxygen systems are widely used by various industries and became known to the public through the space program.

If a wastewater treatment plant is producing oxygen for the activated sludge process, additional oxygen can be produced for introduction into the main intercepting sewers to control the production of hydrogen sulfide. Injection of gaseous oxygen into wastewater by using compressors and diffusers helps maintain aerobic conditions in the sewer.

Disadvantages of using pure oxygen include:

1. Must be kept free of petroleum products.
2. Uses specially designed compressors, dissolution diffusers, and shut down and purge control systems to prevent ignition hazard that could touch off the explosive condition of the oxygen.
3. Must be isolated from public access.

Pure oxygen systems will not be a common alternative to control sulfide in gravity collection systems. These systems have been used effectively to inject oxygen into wastewater in force mains. When evaluated for use in collection systems, an extensive engineering study and design will be required.

6.654 Air

Air is obviously the cheapest chemical available because it is free. There are no hazards to operators involved in handling air. Another advantage of applying air at lift station wet wells is that the resulting turbulence keeps deposits of solids from accumulating during low flows.

A limitation of applying air is the noise from air compressors. The most serious problem using air is the difficulty of transferring sufficient oxygen from the air to the wastewater to produce and maintain aerobic conditions.

6.655 Lime ($Ca(OH)_2$)

Lime can be used to control hydrogen sulfide. Addition of lime can increase the pH of the wastewater to a level where hydrogen sulfide will not exist. A disadvantage of this approach is the problem of disposing of lime sludges.

6.656 Sodium Hydroxide (NaOH)

by Blake Anderson

Sodium hydroxide (caustic soda) has been used extensively by the Los Angeles County Sanitation Districts (LACSD) for many years to control sulfide production in the wastewater collection system for flows under 5 cfs. Periodic treatments of a sewer in which sulfide is produced will usually maintain control. Treatment consists of feeding enough sodium hydroxide into a sewer to raise the pH of the wastewater to 12.5 or greater for a half-hour period. The high pH inactivates the slime layer in the sewer and sulfide production stops. In the average sewer with a sulfide problem, this treatment is necessary every two weeks during the summer. In a few cases more frequent treatment is necessary.

When testing indicates that a sewer is beginning to produce sulfide past an unacceptable level, then treatment is scheduled. "Unacceptable level" is very subjective and difficult to define. In some sewers after treatment the sulfide concentration falls way off and then suddenly jumps back to pretreatment levels after a couple of weeks. This level is clearly unacceptable and treatment should be scheduled. In other sewers the recovery of sulfide production to pretreatment levels may begin slowly at first after a week or so. These slightly inceasing levels can indicate that higher production will shortly return and treatment should be scheduled before problems develop. Only experience will tell you what to expect from a particular sewer.

The sodium hydroxide is hauled to the treatment site in a 2500 gallon vacuum truck[19] purchased by the LACSD for this particular purpose. Parked over an open manhole, the truck feeds the sodium hydroxide through a *ROTAMETER*[20] and into the manhole for 30 minutes. One hundred to 125 gallons of 25 percent sodium hydroxide are required for each cubic foot per second of wastewater flow. The high pH wastewater travels down the sewer and will inactivate the slime layer as long as the pH remains high. Dilution from subsequent sidestreams and neutralization by acidic substances will eventually bring the pH to near neutral levels.

Sodium hydroxide is purchased by the LACSD in large bulk quantities at 50 percent concentration. The sodium hydroxide is diluted to 25 percent concentration in a 15,000 gallon storage tank and held there for future use. Store the sodium hydroxide in the dilute form to reduce its viscosity and to keep it from crystallizing.

Sodium hydroxide also is obtained free by the LACSD as "spent caustic" from industries. This sodium hydroxide is usually at a 3 to 6 percent concentration and is usually combined with other materials. The spent caustic is tested occasionally to determine if it contains the materials of the particular industry in high enough concentrations to be harmful to operators, the environment, or to the wastewater collection system. The major disadvantage of using spent caustic is the large quantity required — usually 2000 gallons per treatment.

Hauling back and forth between the industry and various treatment sites takes a great deal of driver and truck time and usually only one treatment per load is possible. Purchased sodium hydroxide is much more concentrated and several treatments per truck load can be made.

A major consideration when using sodium hydroxide is the side effect that high pH can have on wastewater treatment plants using biological processes. If the sodium hydroxide enters a downstream treatment plant at a high enough pH, an upset of a biological process can occur. If a pH of near 9 or more is anticipated, then bench scale testing should be made to determine the effects of a high pH slug entering the treatment plant. Consult your staff engineer or a consulting engineer for advice in this area.

The LACSD has used several methods to control the effects of high pH on its activated sludge secondary treatment plants. First, there is simple dilution. At some treatment plants the flow is so great that the high pH wastewater coming from the treated sewer line is diluted to near neutral pH levels. Second, there is diversion around the plant. At some treatment plants that have been built to relieve sewer capacity downstream, it is possible to pull stop logs and divert the high pH wastewater around the plant and on to a downstream plant for a short period. Third, there is interception. At one treatment plant the early morning flows are very low. The sodium hydroxide is fed at the treatment site. The 2500 gallon treatment vacuum truck along with an additional 4000 gallon vacuum truck intercept the high pH wastewater three hours later just before it enters the treatment plant. This is accomplished by dropping a stop log in the line to dam the sewer and then pumping the high pH wastewater out of the sewer and into the trucks when it arrives.

Safety is another important consideration when using sodium hydroxide. This is a caustic material that will cause burns. Handling it should be done wearing a face shield and gloves. When treating a sewer line it is important to coordinate with all your maintenance crews and with construction contractors to avoid harming them.

The chief advantage of sodium hydroxide is its lower price compared to other chemicals which require continuous application. Even with the cost of operators and equipment included, the LACSDs have found it much cheaper than the other principal chemical methods. The chief disadvantage is the amount of attention that has to be given to hauling and applying sodium hydroxide. Some of the other chemical methods probably require less attention and time. The economic benefits of using sodium hydroxide vs other chemicals should be determined for each particular collection system. Labor, materials, and equipment should all be included in such an analysis.

6.657 Other Chemicals

Potassium permanganate has been tried and found not to be cost effective in most areas. Ozone generators have been used on a small scale and also found not to be cost effective. Power requirements to produce ozone from the atmosphere or even with pure oxygen available to supply the generator have been very costly to date.

6.66 Summary

Many factors are important for effective control of hydrogen sulfide. You must become aware of the fact that your job involves more than the obvious cleaning of sewers by removing sand and obstructions. You have an active biological system in the sewers. Control of this system will not only affect you directly in regulating corrosion and odor problems, but also will have a direct bearing upon the downstream wastewater treatment plant. You may aid treatment plant digestion by accomplishing some of the breakdown in the sewers; but you also may substantially increase the immediate oxygen demand upon biological treatment processes. Collection system operators need to reach beyond the complexities and difficulties of their mechancial problems and recognize the need to consider the biological ecosystem in the wastewater collection system too.

---

[19] *At one time a 500-gallon tank placed in an old dump truck was used to transport the sodium hydroxide. This equipment is fairly inexpensive and is ideally suited for the needs of a small collection system.*

[20] *Rotameter (ROW-ta-meter.) A device used to measure the flow rate of gases and liquids. The gas or liquid being measured flows vertically up a calibrated tube. Inside the tube is a small ball or a bullet-shaped float (it may rotate) that rises or falls depending on the flow rate. The flow rate may be read on a scale behind the middle of the ball or the top of the float.*

The best method of hydrogen sulfide control is proper collection system design and maintenance. If chemical control is required, chlorine and hydrogen peroxide appear the most feasible. Aeration may be helpful when properly applied at selected locations. Selection of a chemical should be based on an analysis of the magnitude of the problem and a comparison of the costs and effectiveness of the alternatives.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 358.

6.6E What are three potential methods of chemical control of sulfide?

6.6F Why is chlorine effective in controlling sulfide?

6.6G How does hydrogen peroxide control sulfide generation?

6.6H Pure oxygen may be feasible to control sulfide under what conditions?

DISCUSSION AND REVIEW QUESTIONS

Chapter 6. PIPELINE CLEANING AND MAINTENANCE METHODS

(Lesson 5 of 5 Lessons)

Write the answers to these questions in your notebook before continuing to the objective test on page 358. The question numbering continues from Lesson 4.

24. Why is the method of chemical application important and why must it be done correctly?
25. How would you decide whether or not to select an untested chemical? Describe a testing and evaluation procedure.
26. Why must insects and rodents be controlled in a wastewater collection system?
27. What factors contribute to the production of hydrogen sulfide in a collection system?
28. How would you attempt to control odors from a wastewater collection system?

29. What safety precautions must be exercised when using chlorine to control sulfide?
30. Explain the disadvantages of using chemical methods to control sulfide.
31. Why is the proper operation and maintenance of a wastewater collection system important to the operator of a wastewater treatment plant?

SUGGESTED ANSWERS

Chapter 6. PIPELINE CLEANING AND MAINTENANCE METHODS

ANSWERS TO QUESTIONS IN LESSON 1

Answers to questions on page 265.

6.1A To operate and maintain a wastewater collection system properly, try to achieve the following objectives:

1. Minimize the number of stoppages per mile of sewer,
2. Minimize the number of odor complaints, and
3. Minimize the number of lift station failures.

6.1B When a stoppage or blockage occurs in a sewer, wastewater will back up and overflow onto the street or into homes and businesses.

6.1C Major causes of stoppages include obstructions such as roots, grease, debris, broken pipe or joint failures. Vandals, construction work, the forces of nature, and intersecting flows also can cause stoppages.

6.1D To identify the cause of a stoppage, try to identify the source of the problem by determining if:

1. The line has a history of previous stoppages (a root or grease line),
2. Trees are growing near the line,
3. New building sewers or new lateral or branch sewers have been installed recently, and
4. Repairs have been made recently to the sewer or to the street, such as street resurfacing.

Answers to questions on page 272.

6.1E When a grease or root stoppage causes flooding, hand or power rodding is the first method suggested to attempt to clear the stoppage.

6.1F High velocity cleaners are an effective tool for removing grease build ups in sewers up to 24 inches in diameter. A parachute or bag may be a better method for larger diameter sewers.

6.1G A stoppage caused by roots can be cleared by either a power rodder or a hand rodder. A high velocity cleaner also is effective.

6.1H Advantages:

1. Very effective in cleaning flat, slow flowing sewers,
2. Efficient in removing grease, sand, gravel, and debris in smaller diameter sewers,
3. Effective in breaking up solids in manholes and washing structures, and
4. May be used to eliminate emergency stoppages in sewers.

Limitations:

1. Efficiency and effectiveness in removing debris from larger diameter sewers decreases as the cross-sectional area of the pipe is increased, and
2. When used by an inexperienced operator, may cause a back up into residences.

ANSWERS TO QUESTIONS IN LESSON 2

Answers to questions on page 273.

6.2A Three sewer line hydraulic cleaning methods include:

1. Balling,
2. High Velocity Cleaner,
3. Flushing,
4. Sewer Scooter,
5. Kites,
6. Tires, and
7. Poly Pigs.

6.2B When hydraulic cleaning methods are being used, care must be taken to be sure basements and homes are not flooded.

Answers to questions on page 276.

6.21A Balling can remove deposits of inorganics (grit) and grease from sewers.

6.21B Balling is commonly used in preventive maintenance programs because it is very effective in reducing stoppages and economical in comparison with other methods.

6.21C The frequency of balling a sewer in a preventive maintenance program may vary from six months in some sluggish lines to three years in other lines. To determine the frequency of balling, study your district records and base the frequency of cleaning on:

1. Number of stoppages and complaints,
2. Size of area the collection system serves, and
3. Type of wastes carried by collection system.

6.21D Three operators are needed for a balling crew:

1. Maintenance Equipment Operator,
2. Maintenance Man I, and
3. Maintenance Man I.

6.21E Additional water can be obtained from fire hydrants or a water truck to provide the necessary head for a balling operation when flows in the sewer are low.

6.21F The manhole jack or roller is essential to guide the tag line into the sewer without causing unnecessary wear and to give proper rolling action as the tag line is pulled back and forth or in restraining the ball.

6.21G The purpose of an "air gap" device is to prevent the backflow of wastewater into a drinking water supply.

Answers to questions on page 284.

6.21H A sewer ball must be properly inflated to cause good cleaning action, but not so tight the water cannot flow around the ball and carry it downstream. If the ball is too loose, it will only float downstream with little cleaning action.

6.21I Material cleaned from the sewer is caught in the downstream manhole by using a shovel with the spade shaped like the bottom of the sewer. The material is shoveled into a bucket and then removed from the manhole.

6.21J The ball should move downstream slowly at a steady rate.

6.21K A ball could stop moving downstream because:

1. Of a large deposit,
2. Of a build up of material in the line below the ball,
3. The ball has hit a bad tap, and
4. Of crushed or offset pipe.

6.21L To determine what caused the ball to stop moving downsteam:

1. Try to "bounce" the ball back and forth in the line to remove large or stubborn deposits.
2. Consult TV log of line. If line has not been televised or not recently, request that the line be televised.

Answers to questions on page 287.

6.21M To remove a stoppage below a ball, use a power rodding machine, hand rod, or a high velocity cleaner at the downstream manhole.

6.21N The following safety precautions should be taken during a balling operation:

1. Avoid flooding basements, homes, or businesses,
2. Safely route traffic around job site, and
3. Practice manhole safety from start to finish.

Answers to questions on page 292.

6.22A High velocity cleaning machines are used to:

1. Open stoppages,
2. Remove grease,
3. Clean lines of debris, and
4. Wash manholes and wet wells.

6.22B Nozzles attached to the end of the hose create high water velocities that clean the sewers.

6.22C One person can operate the high velocity cleaning machine. The crew consists of two or more persons, depending on field conditions.

Answers to questions on page 292.

6.22D Traffic can be warned of high velocity cleaning units set up in a street by use of:

1. Rotating beacon on top of cab of truck,
2. Flag stands with "Men Working" signs,
3. Safety cones, and
4. Flagmen.

6.22E The water tank should be filled close to the working area because it is difficult and dangerous to drive a truck with a tank full of water.

6.22F To clean a given area or subdivision, start at the top or highest point in the collection system.

6.22G Direct the nozzle upstream in the sewer.

Answers to questions on page 293.

6.22H Send the nozzle up the line and bring it back to the downstream manhole enough times to reach the upstream manhole and return without bringing back debris.

6.22I When loosened materials build up and overflow the debris trap, pull hose and nozzle out of manhole. Retest manhole atmosphere. Allow an operator to enter manhole and shovel debris into a bucket for removal from manhole.

6.22J The nozzle must be kept moving at all times or it could be stuck in the line and cause flooding in homes.

6.22K If flow stops in the working manhole, pull the hose and nozzle out at once and start over again to remove the built up material that is causing the stoppage.

6.22L High velocity cleaning machines clear stoppages by using the forward jet to provide cutting action ahead of the nozzle.

Answers to questions on page 294.

6.22M When cleaning from a manhole to a cleanout, be careful not to knock the cleanout covers out of place or get the nozzle stuck.

6.22N When the nozzle becomes stuck, try:

1. Pulling the nozzle back with the water pressure off, and
2. Moving nozzle to upstream manhole, removing nozzle, and pulling hose back.

6.22O During cold weather, be sure to keep equipment from freezing. The high-pressure pump must be properly drained, the equipment can be heated with a heater, or water can be circulated through the pump and hose.

Answers to questions on page 296.

6.23A Flushing is commonly used at the beginning of the collection system where low or sluggish flows permit the deposition of solids.

6.23B Lower than expected flows at a downstream manhole during a flushing operation indicates that there is a restriction in the upstream segment of the line and that additional cleaning is required.

6.23C Flushing helps control rodents and insects in sewers by sending a sudden surge of water down the line that can wash them out or drown them.

6.23D A flushing crew can consist of two operators *PROVIDED* neither of them enters a manhole. If a manhole must be entered for any reason, such as to remove debris, a third operator must be available so two operators remain topside to retrieve the operator in the manhole if an accident occurs.

Answers to questions on page 297.

6.23E The flushing operation starts at the extreme upstream end of the collection system.

6.23F Manholes are cleaned with a pressure hose by washing the manhole barrels and shelf usually prior to flushing the line.

6.23G Factors that influence the length of line that can be flushed in one day include:

1. The number of manholes that have to be entered and cleaned,
2. Location of manholes — street or backyard easement, and
3. Whether water for flushing is provided by the tank truck or a fire hydrant and its location with respect to the location of the manhole.

6.23H Safety precautions that must be taken during a flushing operation include:

1. Traffic considerations,
2. Atmosphere in manholes (toxic and explosive gases and oxygen level), and
3. Avoid flooding of residences and businesses.

Answers to questions on page 301.

6.24A The cleaning action of a sewer scooter results from the high velocity of water flowing around the shield of the scooter.

6.24B Scooters are capable of removing large objects and such other material as brick, sand, gravel, and rocks. They are considered more effective in larger lines (over 18 inches) and have been used to remove grease in these lines.

6.24C When using a scooter, care must be taken where sewers are shallow to avoid flooding of homes or businesses because of the build up of water in the sewer.

Answers to questions on page 301.

6.24D Three operators are needed for the safe and efficient operation of a scooter crew. When cleaning lines with a 15-inch diameter or larger or in heavy traffic, additional crew members may be needed.

6.24E The debris trap installed in the downstream manhole is designed to allow water to pass and to hold back the debris.

Answers to questions on page 302.

6.24F Before setting equipment up in the street, safety measures need to be taken to warn and control traffic and to insure safe working conditions in manholes.

6.24G The purpose of the manhole jack or control cable guide is to allow the control cable to take the strain without rubbing on the sharp edge of the pipe during the cleaning operation.

6.24H During set up, the level of water in the manhole and sewer above the scooter can be controlled by pulling firmly on the head shield and allowing the excess water to flow on down the sewer.

Answers to questions on page 303.

6.24I To determine if the folding mechanism is working properly when the scooter starts downstream, give the control line a short, smooth pull back two or three feet and hold. If the build up of water in the manhole starts to go down, you will know the folding mechanism is working properly.

6.24J The recommended depth of water in a manhole during a scooter cleaning operation is three times the diameter of the pipe. The deeper the water the more effective the cleaning action, but care must be exercised to avoid flooding homes and businesses.

6.24K If the flow in the collection system is not sufficient for effective cleaning, add more water to the upstream manhole by using water from the tank truck or from a fire hydrant.

6.24L If the scooter slows or stops during the cleaning operation, it is probably due to an accumulation of material ahead of it.

6.24M When material builds up ahead of a scooter, give the control line a short, smooth pull back four or five feet. This will allow the upper half of the head shield to fold back and a surge of water to flush the accumulated material on downstream.

6.24N Someone must watch the flow of material into the lower manhole to prevent a buildup of material that could flow over the debris trap.

6.24O Before debris can be removed from a manhole,

1. Shut off any extra water being put into the upper manhole,
2. Hold up the progress of the scooter,
3. Recheck manhole for gases found in sewers *BEFORE* entering, and
4. Operator entering manhole must have proper safety equipment.

Answers to questions on page 303.

6.24P Cables should be examined at the start and finish of each section to avoid having a cable break when the scooter is in the middle of a sewer.

6.25A Instead of using a sewer ball, larger diameter sewers are cleaned using kites, bags, tires, or a scooter.

6.25B Poly pigs are frequently used to clean force mains.

ANSWERS TO QUESTIONS IN LESSON 3

Answers to questions on page 308.

6.31A Sewer line mechanical clearing techniques include:

1. Bucket machines,
2. Power rodders, and
3. Hand rods.

6.31B Hydraulic cleaning techniques should be given first consideration for removing solids deposited in sewers because of simplicity and costs.

6.31C Hydraulic cleaning techniques may not be the best solution for removing roots or debris that enter the collection system from breaks or repairs in pipes or manholes or from some types of industrial waste discharges. Nozzle action from a high velocity cleaner can develop a negative pressure that could hasten the collapse of a bad section of pipe.

6.31D Power bucket machines should be used mainly to remove debris from a break or other debris that cannot be removed by hydraulic cleaning techniques. They should not be used as a routine cleaning tool on a regular basis.

Answers to questions on page 314.

6.31E The working machine pulls the bucket out of the manhole.

6.31F The porcupine tool is quite effective for final clean up since the bristles have a scrubbing action.

6.31G A power bucket crew should consist of at least three operators and four operators are recommended.

Answers to questions on page 315.

6.31H An overnight line might be left in a sewer line overnight if the job is not completed before the end of the day. The overnight line is used to speed start up the next day and avoid the time and effort to thread the sewer again.

6.31I A fool-proof communication system must be devised and used because someone can easily be injured if the proper signal is not sent, received, or is misunderstood.

6.31J The purpose of the swivel is to keep the rope and cable from twisting.

Answers to questions on page 316.

6.31K Usually the size of clearing bucket is determined by the size of the sewer being cleared. Experience and history of the sewer may dictate the use of a bucket smaller than the actual sewer size. Also the size of the manhole opening limits the maximum size of the clearing bucket.

6.31L As the bucket is pulled upstream into the material deposited in the sewer, a definite resistance can be noticed when the bucket is full. Always make a few short pulls to check out not only the amount of material, but also the equipment and the set up.

6.31M The debris in the bucket is first dumped on the street and then loaded and hauled away or dumped into a loading chute that moves the debris directly into a dump truck.

6.31N A sand trap is inserted in the downstream manhole to catch debris loosened by the bucket, but not retained in the bucket.

6.31O The line may be cleaned with a porcupine cleaning tool after a bucket has been pulled through the line.

6.31P The porcupine should be pulled downstream because it can seal off or plug the line and cause the wastewater to back up in the line.

6.31Q The bucket should be pulled upstream to minimize stoppages that could develop when large amounts of debris or roots are encountered.

Answers to questions on page 317.

6.31R The location of the bucket in the sewer line must be known at all times so if it ever becomes stuck, it can be dug up.

6.31S The condition of the equipment should be inspected regularly to avoid breakdowns. If a cable should come loose from the bucket, it could be very difficult to retrieve the bucket.

6.31T When working around cable operated equipment, keep your hands clear of the drum. Use a manhole hook to guide the cable. In an instant, your hand or fingers can become entangled and the operator cannot stop the machine fast enough to avoid injury.

6.31U Locations of problem areas must be recorded so future cleaning crews will know what to expect and hopefully avoid serious problems. Also it may become necessary to repair a sewer and this too should be noted for future reference.

Answers to questions on page 319.

6.32A Power rodders can be used for:

1. Routine preventive maintenance,
2. Scheduled clearing of grease deposits, roots, and flat lines,
3. Threading cable for other cleaning equipment, and
4. Emergency use for stoppages.

6.32B Sectional power rodders are capable of clearing lines with diameters up to 12 inches and distances up to approximately 750 feet.

6.32C Advantages of sectional rod:

1. When a rod is broken, this section can be replaced,
2. Repair can be done quickly in the field, and
3. The broken section can be replaced with a new section at once or the rod can be recoupled, adding new rod only when more footage is needed.

6.32D Advantages of continuous rod:

1. Greater distances can be obtained, and
2. Loading the machine with new rod is fast and simple.

Answers to questions on page 325.

6.32E Two operators are needed to properly operate the power rodder and three are recomended.

6.32F When a two-operator crew has to enter a manhole, they must obtain assistance before anyone enters a manhole. Two operators must be topside at all times when someone enters a manhole.

6.32G A round-stock corkscrew is a first-step clearing tool for rodding where conditions are unknown.

6.32H Spring blade cutters can be used to remove grease.

6.32I Power rodders are more effective in smaller lines.

Answers to questions on page 325.

6.32J A sewer may be rodded either upstream or downstream from a manhole.

6.32K The purpose of the leader tool installed on the end of the rod is to prevent the sharp end of the rod from damaging the interior of the guide hose.

6.32L A debris trap is necessary to keep loosened roots, grease chunks or other material from going farther downstream and possibly causing a stoppage.

Answers to questions on page 327.

6.32M To determine which clearing tool to use,

1. Study history of line being cleared,
2. Look for grease in manhole, and
3. Look for trees growing close to the sewer.

6.32N Use a round-stock corkscrew to try to clear a stoppage.

6.32O After a stoppage has been cleared, examine the material at the downstream manhole and try to determine if the stoppage was caused by grease, grit, or roots. When the probable cause of the problem has been identified, then select the best tool to correct the problem.

6.32P When changing to another clearing tool, NEVER take hold of the clearing tool until it has stopped rotating and the power rodder is shut down. Also be careful the rod is not coiled in the sewer and won't unwind from this torque when the tool is moved about.

6.32Q The location of the clearing tool in the sewer must be known at all times so if the tool ever gets stuck, you will know exactly where to dig to recover the tool and open the sewer.

6.32R The speed of the rod in or out, and the rotation speed, depend primarily on existing conditions in the sewer and also upon the experience of the operator.

6.32S Water is sometimes added to the opposite manhole during power rodding if existing flows are insufficient in order to keep the rod cool and to increase the effectiveness of the clearing operation.

Answers to questions on page 327.

6.32T Use a pick-up tool to recover a broken rod.

6.32U Broken rods must be recovered. If they can't be recovered by a pick-up tool or flushed out with a high velocity cleaner, the line must be dug up to recover the tool.

Answers to questions on page 328.

6.32V Rods and clearing tools can be under tension and can be very dangerous if they get away from you.

6.32W Occasionally the rod should be run out on the top of the ground and inspected for bent pieces and loose couplings. When couplings are allowed to stay loose, the rod will wear and become weak at that point.

6.32X The rod should be cleaned when it is returned to the reel to prevent the buildup of grease and grit which will cause wear on the rod.

6.32Y Everyone on a rodding crew must know their own job and everyone else's job so everyone can be familiar with the over-all operation.

6.32Z The engine of the power rodder should have the maintenance and care as recommended by the shop foreman or manufacturer's directions.

Answers to questions on page 331.

6.33A Hand rods are used to clear many stoppages, especially during the night or on weekends.

6.33B A hand rodding crew usually consists of two operators. They never enter manholes. When a manhole must be entered, a third operator must be available in case the operator in the manhole needs help.

6.33C A power rod has a greater penetration into a sewer than a hand rod.

6.33D When a bare rod is exposed on top of the ground or street, care must be taken that the rod does not injure someone or damage equipment and gardens.

Answers to questions on page 332.

6.33E The kind of tool used at the end of the rod depends on the sewer's condition and the type or source of the problem we are trying to correct.

6.33F If hand turning a rod does not clear the stoppage, put the gasoline driven power drive unit on the rod and use this unit. If this procedure doesn't work, try the power rodder.

6.33G When working a rod upstream to clear a stoppage, be careful that the surge of water that is released when the stoppage is broken does not:

  1. Shoot up the rod guide tube and get someone wet, and
  2. Force the rod back out the guide tube.

ANSWERS TO QUESTIONS IN LESSON 4

Answers to questions on page 333.

6.4A Cleaning equipment must be properly maintained at all times so we can do our jobs quickly and effectively.

6.4B An operator can learn how to maintain cleaning equipment from the manufacturer's directions and from experience.

6.4C The objective of cleaning equipment maintenance is to keep equipment in an existing state of repair and efficiency and to preserve equipment from failure.

6.4D The three essential factors for an effective equipment PREVENTIVE maintenance program are TOOLS, TIME, and TALENT (knowledge).

6.4E The crew foreman or equipment operator is responsible for the proper maintenance of cleaning equipment.

Answers to questions on page 334.

6.4F Bucket machine crews should have enough tools for both upstream and downstream machines because often the crew is considerable distance apart, especially when working on easements.

6.4G The number one maintenance problem with the cable scroll and level wind system is lack of proper lubrication.

6.4H Cable clamps should be tightened at the start of each day.

6.4I When a bend is noted in a stablizer leg, get it straightened now.

Answers to questions on page 335.

6.4J If the tension on the drive head chain is loose, the drive dogs tend to ride up and over rod couplings.

6.4K The torque on the drive rollers of a continuous rodder depend on the rod wear.

6.4L Maintenance of hydraulic units includes:

  1. Looking for and repairing leaky fittings and hoses,
  2. Keeping oil filter clean, and
  3. Maintaining proper hydraulic oil level.

Answers to questions on page 337.

6.4M The operator of a high velocity cleaner unit must be familiar with all aspects of the machine so the operator can properly operate and maintain the unit.

6.4N When operating a high velocity cleaner, always be alert for:

  1. Odd or suspicious sounds,
  2. Higher or lower than usual RPM to maintain pressure, and
  3. Sluggish reel return.

6.4O Daily check oil levels of:

1. Engine,
2. Pressure pump, and
3. Hydraulic-oil tank.

6.4P Cold weather maintenance includes:

1. Draining pump daily, and
2. Covering rear canopy openings.

ANSWERS TO QUESTIONS IN LESSON 5

Answers to questions on page 340.

6.5A Chemicals can be used to control roots, odors, corrosion, rodents and insects.

6.5B Some people are reluctant to use chemicals to solve sewer problems because of past unfortunate experiences.

6.5C Doing nothing might be better than trying an untested chemical because even if the chemical didn't work, you might have to pay chemical costs and equipment and labor costs for application.

6.5D Metal chips and filings should not be put into a sewer because they will probably settle out in the sewer without reacting. If they do react, they will produce hydrogen gas which could produce an explosive mixture.

6.5E Before developing a testing program, calculate the cost per foot of sewer tested for buying and applying the chemical and testing the chemical to determine if it will be harmful to the wastewater treatment plant or a watercourse.

Answers to questions on page 342.

6.5F When roots are cut in a sewer, the roots will send out new growth just back from the cutting. Also the root will increase in diameter and break the pipe or open up the joint even more.

6.5G Before starting a chemical program for root control, obtain the following information from the manufacturer:

1. Recommended herbicide and EPA approval number,
2. Method of application,
3. Concentration and amount of chemical needed,
4. Contact time,
5. Preferred meteorological conditions.
6. Total cost for chemicals and application,
7. Hazards to downstream operators,
8. Effects on downstream wastewater treatment plant, and
9. Effects on receiving waters of plant effluent.

6.5H Chemicals can be applied for root control by flooding, spraying, and foaming techniques.

6.5I Homes and businesses can become flooded during a chemical operation during the chemical contact period because the section being chemically treated is plugged off from the rest of the system. Wastewater will build up behind the plugged upstream manhole and could cause flooding.

6.5J Chemicals used for root control can be recovered and recycled by carefully moving the chemical operation down the sewer. After one contact period is over, plug the lower end of the next downstream section to be chemically treated. Release the chemicals from the upstream section and they will be "caught" in the downstream section. Also the chemicals can be pumped from one section into a tank and transported to the next section to be chemically treated.

6.5K When chemically treating roots, always read the label on the chemical container, wear protective clothing, and know what to do if an accident occurs.

Answers to questions on page 344.

6.5L Sources of grease in wastewater collection systems include restaurants, industries and homes with garbage grinders.

6.5M Odors from a wastewater collection system can be controlled by proper design, cleaning and maintenance methods.

6.5N Use of masking agents to overcome odors does not

1. Correct the problem or cause of the odors, but
2. Masks the odor of hydrogen sulfide so you may not be aware of the presence of this toxic, flammable and explosive gas. Also hydrogen sulfide can be converted to sulfuric acid which is very corrosive.

6.5O Insects and rodents in a wastewater collection system should be controlled for the safety and protection of collection system operators and the public.

Answers to questions on page 347.

6.6A Problems created by hydrogen sulfide include:

1. Paralysis of the respiratory center and death of operators,
2. Rotten egg odors,
3. Corrosion and possible collapse of sewers, structures and equipment, and
4. Loss of capacity of sewer.

6.6B Hydrogen sulfide in sewers comes from the reduction of sulfate ($SO_4^=$) to sulfide ($S^=$) by bacteria in the slimes in sewers. Materials containing proteins in the wastes are an equally important food for bacteria that produce hydrogen sulfide. Any sulfur containing compound that is available as a food for slimes that reduce oxygen in the wastewater can produce odorous reduced sulfur compounds, including hydrogen sulfide.

6.6C Factors that are important in the production of hydrogen sulfide include:

1. Design,
2. Cleaning procedures,
3. Maintenance program,
4. Materials,
5. Slimes,
6. pH,
7. BOD,
8. Temperature,
9. Slope of sewer,

10. Flow (full capacity?),
11. Velocity and turbulence, and
12. Age of system.

6.6D Collection system maintenance has a definite effect on the rate of degradation of wastewater in the collection system. Undesirable impacts of degradation on the wastewater treatment plant include:

1. Odor and corrosion problems in plant facilities, and
2. Initial or immediate oxygen demand on biological treatment processes.

Answers to questions on page 351.

6.6E Three potential methods of chemical control of sulfide include:

1. Chlorine,
2. Hydrogen peroxide,
3. Pure oxygen,
4. Air,
5. Lime for pH control, and
6. Sodium hydroxide for pH control.

6.6F Chlorine is effective in controlling sulfide because it is toxic to aerobic bacteria that can cause anaerobic conditions and also toxic to organisms that convert sulfate to sulfide.

6.6G Hydrogen peroxide controls sulfide generation by:

1. Keeping wastewater aerobic (sulfide forms only under anaerobic conditions), and
2. Combining with hydrogen sulfide to produce elemental sulfur.

6.6H Pure oxygen may be feasible to control sulfide in intercepting sewers when the wastewater treatment plant uses pure oxygen in the activated sludge process.

9. 1. 2. 5.
10. 19. 20.
3. 4. 6.
11. 23. 12. 18.
8. 7. 15.
13. 24. 21.
14. 16. 22.

OBJECTIVE TEST

Chapter 6. PIPELINE CLEANING AND MAINTENANCE METHODS

Please mark correct answers on answer sheet as directed at the end of Chapter 1. There may be more than one correct answer to each question.

TRUE-FALSE

1. After clearing a large septic stoppage, be sure to notify the operator of the downstream wastewater treatment plant.
   1. True
   2. False

2. The purpose of an air gap device is to provide adequate space above the top of a manhole and the end of a fire hose from a fire hydrant.
   1. True
   2. False

3. When operating a high velocity cleaner, the nozzle should be stopped at a heavy grease deposit until the grease is washed away.
   1. True
   2. False

4. Never use rubber gloves while handling or guiding a rod that is turning.
   1. True
   2. False

5. Chemical treatment usually is a cheap solution for a continuous odor problem.
   1. True
   2. False

MULTIPLE CHOICE:

6. An air gap device is a(n)
    1. Horizontal empty space.
    2. Open vertical drop.
    3. Space between manholes.
    4. Space between water and pump suction.
    5. Vertical empty space.

7. To operate and maintain a wastewater collection system so it will function as intended, operators should try to minimize the number of
    1. Feet of sewer televised per day.
    2. Lift station failures.
    3. Miles of sewer cleaned per day.
    4. Odor complaints.
    5. Stoppages per mile of sewer.

8. Obstructions causing stoppages in sewers include
    1. Broken pipe.
    2. Grease.
    3. Manholes.
    4. People.
    5. Roots.

9. Stoppages in sewers may be caused by
    1. Bacteria cultures.
    2. Careless plumbers.
    3. Forces-of-nature.
    4. Obstructions.
    5. People not realizing what they are doing.

10. Types of debris which can cause stoppages in sewers include
    1. Broken pipe.
    2. Dissolved solids.
    3. Grease.
    4. Rags.
    5. Soluble BOD.

11. Sewer cleaning and maintenance methods depend on the
    1. Condition of the sewer.
    2. Fluctuations in wastewater flows.
    3. Grade of the sewer.
    4. Pipe materials.
    5. Recordkeeping system.

12. Hydraulic methods of cleaning stoppages in sewers consist of using equipment that _____ the material out of the pipe.
    1. Cuts
    2. Pulls
    3. Pushes
    4. Scrapes
    5. Washes

13. Hydraulic sewer cleaning equipment includes
    1. Bags.
    2. Balls.
    3. Bucket machines.
    4. Kites.
    5. Scooters.

14. Mechanical sewer clearing equipment includes
    1. Bucket machines.
    2. Hand rods.
    3. High velocity cleaners.
    4. Power rodders.
    5. Scooters.

15. Types of sewer clearing equipment that must be used with caution in areas where homes have basement plumbing fixtures include
    1. Bucket machines.
    2. High velocity cleaners.
    3. Kites.
    4. Power rodders.
    5. Sewer balls.

16. An emergency stoppage in a sewer may be cleared by
    1. Balling.
    2. Bucket machines.
    3. Chemicals.
    4. High velocity cleaning.
    5. Power rodding.

17. Roots in a sewer may be cleared by
    1. Bacteria cultures.
    2. Balling.
    3. Chemicals.
    4. Power rodders.
    5. Scooters.

18. Odor problems in sewers can be controlled by
    1. Bacteria cultures.
    2. Balling.
    3. Chemicals.
    4. Hand rods.
    5. High velocity cleaners.

19. When should a wastewater collection system operator notify the operator of a downstream wastewater treatment plant?
    1. After clearing a large septic stoppage
    2. After cutting out some roots
    3. After quitting work for the day
    4. When the high velocity cleaner is broken
    5. When some grease has been cleaned out of a sewer

20. Hydraulic sewer cleaning methods can be used to remove _____ from sewers.
    1. Debris
    2. Grease
    3. Odors
    4. Roots
    5. Sand

21. Use a hydrant gate valve to throttle flows from a fire hydrant because using the hydrant's valve may cause
    1. A cross-connection.
    2. An air gap.
    3. Backsiphonage.
    4. Flow out through weep hole and undermine the hydrant.
    5. Water hammer in the distribution system.

22. Hydraulic sewer cleaning methods which do a much better job than flushing include
    1. Balling.
    2. Bucket machines.
    3. Chemicals.
    4. High velocity cleaners.
    5. Power rodders.

23. Before anyone ever enters a manhole, the atmosphere in the manhole must be tested for
    1. Explosive gases.
    2. Nitrogen gas.
    3. Oxygen level.
    4. Relative humidity.
    5. Toxic gases.

24. Mechanical techniques used for cleaning sewers include
    1. Balling.
    2. Hand rods.
    3. High velocity cleaners.
    4. Power bucket machines.
    5. Power rodders.

25. Power rodders can be used for
    1. Cleaning sewers.
    2. Clearing emergency stoppages.
    3. Clearing grease deposits.
    4. Cutting roots.
    5. Threading cable for TV inspection.

26. Necessary sectional rodder maintenance items that can easily be done on the job include
    1. Examining the wear on the rod guide bushings.
    2. Inspecting for loose rod couplings.
    3. Keeping drive head chain tight.
    4. Looking for worn drive dogs.
    5. Maintaining proper torque on the drive rollers.

27. Necessary continuous rodder maintenance items that can easily be done on the job include
    1. Examining for wear on the rod guide bushing.
    2. Inspecting for improperly adjusted belts.
    3. Inspecting teeth on drive gears.
    4. Keeping drive head chain tight.
    5. Looking for leaky fittings on hydraulic units.

28. Hand rods are used
    1. As a quick and simple answer to many stoppages.
    2. Extensively for emergencies at night.
    3. On service request trucks.
    4. To clean sewers during off hours.
    5. When and where modern methods cannot be used effectively.

29. When operating a high velocity cleaner, a sluggish reel return may be caused by
    1. Air leaking into system.
    2. Belts slipping.
    3. Filter needs replacing.
    4. Leak in a hydraulic control.
    5. Low hydraulic oil supply.

30. When starting a chemical program for root control, information that must be obtained from the chemical manufacturer includes
    1. Concentration of chemical applied to roots.
    2. EPA approval number.
    3. Frequency of high velocity cleaning of line.
    4. Hazards to operators working downstream from root control section of sewer.
    5. Recommended method of application.

31. Methods of controlling roots in sewers include
    1. Application of chemicals.
    2. Balling.
    3. Flushing.
    4. Inserting a liner in the sewer.
    5. Not allowing trees to be planted over sewers.

32. Undesirable impacts at a wastewater treatment plant as a result of degradation of wastewater in the collection system include
    1. Corrosion problems.
    2. Grit accumulation in wet wells.
    3. Immediate oxygen demand on biological treatment processes.
    4. Odor problems.
    5. Slime build up problems.

33. Which of the following precautions should be taken or at least considered before or during a balling operation?
    1. Care not to flood homes or businesses
    2. Proper routing of traffic
    3. Three-operator crew if someone must enter a manhole
    4. Try to avoid causing a stoppage downstream from the ball
    5. Use of flagmen if necessary

34. What information should be contained in the record or log of a hydraulic cleaning operation?
    1. Amount of flow in a sewer
    2. Traffic patterns
    3. Type and amount of material removed from downstream manhole
    4. Volume of water needed from fire hydrants
    5. Where obstructions were encountered

35. Proper selection and application of chemicals in a wastewater collection system can be helpful to control
    1. Birds.
    2. Grease.
    3. Rodents.
    4. Roots.
    5. Toxic pesticides.

36. Chemicals may be applied by which of the following techniques?
    1. Calculating
    2. Flooding
    3. Foaming
    4. Oxidation
    5. Spraying

37. Before applying any chemicals to a sewer, which of the following items must be done?
    1. Be able to take the proper action if an accident occurs
    2. Know how to mix and apply the chemical
    3. Read the label on the chemical container
    4. Study chemistry
    5. Understand the type of chemical reaction that will occur

38. Odor problems in wastewater collection systems usually result from
    1. High temperatures.
    2. Long transmission lines (sewers).
    3. Low velocities.
    4. Rodents.
    5. Skunks.

39. Rodents and insects can be controlled by
    1. Hoping they will go away.
    2. Keeping manholes and sewers clean.
    3. Spraying manholes with an approved pesticide.
    4. Waiting for the weather to change.
    5. Working with local health and/or animal control officials.

40. Why should hydrogen sulfide be controlled?
    1. To prevent decay of wastes
    2. To prevent odors
    3. To protect operators
    4. To protect sewers and structures from corrosion
    5. To protect the environment in receiving waters

41. The amount of hydrogen sulfide produced in a sewer depends on
    1. Amount of odor present.
    2. Anaerobic conditions.
    3. Flow velocity.
    4. pH.
    5. Temperature of wastewater.

42. What items would you consider when selecting a solution to clear a stoppage in a sewer (assume no flow is going through stoppage)?
    1. Add a solution to the upstream manhole to clear the stoppage
    2. Identify cause of stoppage
    3. Tools and equipment available to clear stoppage
    4. Urgency of clearing stoppage
    5. Use of chemicals

43. The purpose of an air gap device is to
    1. Aerate wastewater in a sewer to prevent the formation of hydrogen sulfide.
    2. Allow a gap for wastewater to flow out a manhole and not come in contact with a hose or pipe containing drinking water.
    3. Allow a gap in the pipe.
    4. Keep wastewater from flowing back into the water supply lines.
    5. Let the air flow.

44. A sand or debris trap
    1. Could be used with a rodding operation.
    2. Has steel trap jaws.
    3. Retards flow in the downstream manhole.
    4. Should be used instead of shoveling debris if hydrogen sulfide gas is a problem in the manhole.
    5. Should be used with a high velocity cleaner.

45. Precautions taken with regard to operating a high velocity cleaning machine include
    1. Avoid knocking out covers of cleanouts.
    2. Care not to flood homes or basements.
    3. Not allowing an inexperienced operator to operate the machine alone.
    4. The velocity of the nozzle from getting too high.
    5. Try not to allow nozzle to get stuck in sewer.

46. What factors must be considered when operating a power rodder?
    1. Do not jam rodding tool into an obstruction
    2. Do not rotate the rod
    3. Do not rotate the rod in one position for extended periods
    4. If a rod should break, make sure all the torque is out of it before handling it
    5. Use as much power as possible

47. Why must you always know where a cleaning tool is in a sewer?
    1. So the tool can be located and dug up if it gets stuck
    2. So the tool can find its way back
    3. So you can avoid stopping in front of and plugging up service lines
    4. So you can locate it after a restbreak
    5. So you know where obstructions or difficulties are encountered

48. When evaluating the application of chemicals to a problem in a sewer, remember that the chemicals
    1. Are a permanent solution.
    2. Correct the source.
    3. Perform the same in the field as in the lab.
    4. Require consideration of the safety of the operators and the public.
    5. Will travel down the sewer to a stoppage.

49. Steps to follow when developing a chemical testing program include
    1. Agree in writing what results should be produced.
    2. Compare cost of chemical program with other alternatives.
    3. Document claims and procedures in writing.
    4. Keep good records before, during and after testing program.
    5. Photograph or video tape problems in test section before application of chemicals.

REVIEW QUESTIONS

50. Why should flow velocities in sewers be measured in the field?
    1. To determine if a stoppage might be developing in the sewer
    2. To determine if the operator can calculate the flow velocity knowing the distance and travel time for a float or dye
    3. To determine the actual velocity in a sewer
    4. To find out if solids might be settling out in the sewer.
    5. Velocities do not have to be measured in the field if velocities are shown on the plans

51. When reviewing plans and specifications.
    1. Be sure the engineer has calculated the volume of trench excavation properly.
    2. Be sure there is sufficient overhead clearance for cranes where they might be needed.
    3. Be sure traffic can be safely routed around manholes when necessary.
    4. Determine if your existing maintenance equipment can be used in the new system.
    5. Look for provisions for natural ventilation to reduce problems caused by gases found in sewers.

52. Dye tests are conducted to find the location of
    1. Illegal connections.
    2. Roots in a sewer.
    3. Surface inflow.
    4. TV camera caught or wedged in a sewer.
    5. Yard drain connected to building sewer.

END OF OBJECTIVE TEST

CHAPTER 7

UNDERGROUND REPAIR

by

William Puthuff, Jim Hicks, Mel Arts, John Dolenga

John Cavoretto and Gene Turney

Revised by

Bob Hiler

TABLE OF CONTENTS

Chapter 7. Underground Repair

Page

OBJECTIVES 367

GLOSSARY 368

LESSON 1

7.1 Underground Work 369
  7.11 Safety Considerations 369
  7.12 Types of Underground Work 369
  7.13 Demand for Repair 369
  7.14 Sources of Damages and Stoppages 370
    7.141 Roots 370
    7.142 Improper Taps 370
    7.143 Damage by the Public or Other Utility Agencies 370
  7.15 Work Request Form 370
  7.16 Assignment of Repair Job 370
    7.161 Investigate and Plan Job 374
    7.162 Meet with Utility Companies 374
    7.163 Public Relations 374
    7.164 Preconstruction Meeting 374

7.2 Shoring 375
  7.21 Shoring Requirements 375
  7.22 Responsibility 376
  7.23 Placing of Spoils (Excavated Material) 376
  7.24 Shoring Regulations 377
    7.241 Operator Safety 377
    7.242 Soil Conditions and Trench Location 377
    7.243 Sloping Excavation Walls 377
    7.244 Access to Construction Work Area 377
    7.245 Pedestrian Safety 377

7.25 Types of Shores 378
  7.251 Hydraulic Shores 378
  7.252 Screw Jacks 381
  7.253 Air Shores 382
  7.254 Solid Sheeting 383
  7.255 Cylinder Shoring 386
  7.256 Shield Shoring 387
7.26 Shoring Summary 391

LESSON 2

7.3 Repair of Service Lines 394
  7.31 Preliminary Investigation 394
  7.32 Job Assignment to Repair Crew 395
  7.33 Equipment, Materials and Tools 395
  7.34 Arrival at Job Site 397
  7.35 Starting Repair (Excavation) 398
  7.36 Cutting Pipe 399
  7.37 Install Cleanout 399
  7.38 Bedding, Backfilling and Compaction 399
  7.39 Complete Service Line Location Card 399
7.4 Main Line Repair 401
  7.41 Preliminary Field Investigation 401
  7.42 Crew and Assignment 401
  7.43 Materials, Equipment and Tools 401
  7.44 Arrival at Job Site 401
  7.45 Cutting Pavement 402
  7.46 Excavation 402
  7.47 Pipe Repair 402
  7.48 Bedding, Backfilling and Compaction 403
  7.49 Safety 403
7.5 Spanning Excavations 404

LESSON 3

7.6 Sealing Grout 405
  7.61 Reasons for Grouting or Sealing Sewers 405
  7.62 Equipment 405
  7.63 Sealing Chemicals 406

- 7.64 Sealing Process 406
  - 7.641 Set Up 406
  - 7.642 In Line 406
  - 7.643 Testing and Sealing 408
  - 7.644 Clean Up 408
- 7.65 Specialized Applications 408
  - 7.651 Roots 408
  - 7.652 Large Diameter Pipe Sealing 408
- 7.66 Acknowledgements 410

7.7 Guniting Sewers 410

7.8 Manhole Repairs 410

- 7.81 Raising Manhole Frame and Cover to Grade 410
  - 7.811 Detection of Missing Manholes 410
  - 7.812 Site Preparation 412
  - 7.813 Raising the Frame and Cover 414
- 7.82 Repair of Manhole Bottoms 415
  - 7.821 Manholes Without Concrete Bottoms 415
  - 7.822 Manholes With Flat Bottoms 415
  - 7.823 Channel Corrections 416
- 7.83 Inside Drops in Manholes 416
  - 7.831 Materials Used for Inside Drops 416
  - 7.832 Installation of Inside Drops 416
- 7.84 Repair of Manhole Barrels 416

7.9 New Construction 418

Suggested Answers 419

OBJECTIVE TEST 422

OBJECTIVES

Chapter 7. UNDERGROUND REPAIR

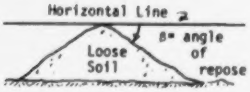
After completion of Chapter 7 you should be able to do the following:

1. Safely repair or construct sewer lines and manholes,
2. Determine need for shoring and properly select and use shoring,
3. Describe shoring regulations,
4. Excavate, repair and backfill service lines,
5. Excavate, repair and backfill main lines,
6. Raise manhole frame and cover to grade,
7. Repair and install manhole bottoms,
8. Install sewers spanning excavations, and
9. Seal leaky sewers by grouting.

GLOSSARY

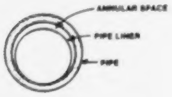
ANGLE OF REPOSE **ANGLE OF REPOSE**

The angle between a horizontal line and the slope or surface of unsupported material such as gravel, sand or loose soil. Also called the "natural slope."



ANNULAR SPACE (AN-ul-are) **ANNULAR SPACE**

A ring-shaped space. For example, the space between the outside of a pipe liner and the inside of a pipe.



CROSS BRACES **CROSS BRACES**

Shoring members placed across a trench to hold other horizontal and vertical shoring members in place.

EASEMENT **EASEMENT**

Legal right to use the property of others for a specific purpose. For example, a utility company may have a five-foot easement along the east property line of a home. This gives the utility the legal right to install and operate a sewer line within the easement.

GUNITE **GUNITE**

A mixture of sand and cement applied pneumatically that forms a high density, resistant concrete.

MAIN LINE **MAIN LINE**

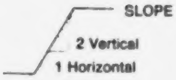
Branch or lateral sewers that collect wastewater from building sewers and service lines.

SHEETING **SHEETING**

Solid material, such as wooden sheets or metal plates, used to hold back soil and prevent cave-ins.

SLOPE **SLOPE**

The slope or inclination of a sewer or trench excavation is the ratio of the vertical distance to the horizontal distance or "rise over run."



2:1 trench side slope

SPOIL **SPOIL**

Excavated material such as the soil from the trench of a sewer.

STRINGERS **STRINGERS**

Horizontal shoring members, usually square, rough cut timber, that are used to hold solid sheeting, braces or vertical shoring members in place. Also called WALERS.

SURCHARGE **SURCHARGE**

Sewers are surcharged when the supply of water to be carried is greater than the capacity of the pipes to carry the flow. The surface of the wastewater in manholes rises above the top of the sewer pipe, and the sewer is under pressure or a head, rather than at atmospheric pressure.

UPRIGHTS **UPRIGHTS**

Vertical shoring members that may be solid (SHEETING) or spaced from 2 to 8 feet apart to prevent cave-ins.

WALERS (WAY-lers) **WALERS**

Horizontal shoring members, usually square, rough cut timber, that are used to hold solid sheeting, braces or vertical shoring members in place. Also called STRINGERS.

CHAPTER 7. UNDERGROUND REPAIR

(Lesson 1 of 3 Lessons)

7.1 UNDERGROUND WORK

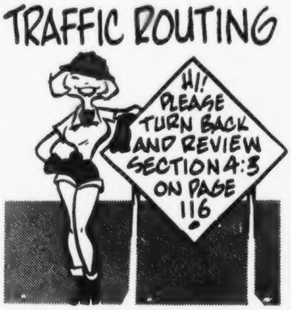
This chapter discusses repair of sewer service lines, main lines and manholes.

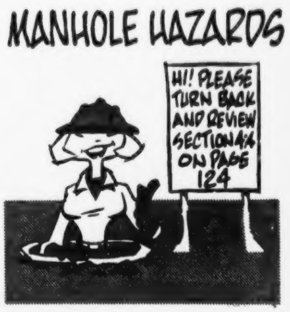
7.11 Safety Considerations

Underground work can be very hazardous. Whenever excavation is necessary to repair a sewer line or manhole, precautions must be taken to protect operators from cave-ins and also from dangerous gases and fumes. Precautions during excavation include adequate shoring and ventilation. Other safety considerations include protecting

1. Operators from traffic,
2. Public from injury,
3. Operators from injury, and
4. Public and private property, including other utilities.

Also traffic must be routed safely around the job site. See Chapter 4, Section 4.1, Traffic and Manhole Safety for additional details.


TRAFFIC ROUTING
HI! PLEASE TURN BACK AND REVIEW SECTION 4:3 ON PAGE 116


MANHOLE HAZARDS
HI! PLEASE TURN BACK AND REVIEW SECTION 4:4 ON PAGE 124

7.12 Types of Underground Work

Repair and new construction work consist of working on or installing service lines and manholes located on private property or streets and main lines and manholes located in rear easements and streets. Wastewater collection system repairs are necessary to correct damage to pipe or to remove an obstruction that is preventing the proper function of the collection system. Damage to pipe may occur through natural forces, but a large percent of repair jobs may be caused by poor design or poor workmanship during construction and later additions to the system.

7.13 Demand for Repair

A request to repair a line may originate from a user who is not being provided service due to collection system failure or from the agency's inspection or *PREVENTIVE MAINTENANCE UNITS.*[1] If the request for repair originates from an agency's emergency service crew, they may have restored service and in so doing discovered a damaged pipe that must be repaired or an obstrcution that must be removed.

Work request forms (see Section 7.15) provide an organized approach for other crews to notify a repair crew that a line needs repairs. Whenever an emergency crew, TV inspection crew, or preventive maintenance crew discovers a situation needing repair, a work request form is completed and delivered to a supervisor. The supervisor reviews work requests and assigns them to a repair crew. Examples of various types of defects located and identified by emergency crews or preventive maintenance crews are given in the following sections.

---

[1] *Preventive maintenance units. Crews assigned the task of cleaning sewers (for example balling or high velocity cleaning crews) to prevent stoppages and odor complaints. Preventive maintenance is performing the most effective cleaning procedure, in the area where it is most needed, at the proper time.*

7.14 Sources of Damages and Stoppages

Sewer lines may have to be dug up because they are damaged or blocked. Causes of these problems are described and shown in this section.

7.141 Roots

Roots often enter pipes through cracks and cause stoppages. Figure 7.1 shows a cracked pipe that was dug up with roots growing around it. Probable cause of pipe damage in Figure 7.1 is improper bedding (such as large stones) that caused pipe to crack and allowed roots to enter the pipe. These roots may prevent inspection or cleaning equipment from passing through a sewer.

7.142 Improper Taps

Improper taps prevent either building and/or branch and lateral sewers from functioning as intended. Various types of improper taps include:

1. Protruding taps,
2. Cracks or holes that allow root entry, leaks and concrete to enter the sewers,
3. Insufficient opening in tap, and
4. Misalignment of tap.

A tap protruding into a main line can cause material to build up and stop the flow in the main line (Fig. 7.2). Also it can prevent inspection and cleaning equipment from passing by the tap. To repair a protruding tap, remove a section of the main line containing the tap and install a factory made wye or tee and connect it to the building sewer. A protruding tap may be prevented by cutting a hole in the main line with a can-type cutter and installing a proper saddle.

An improper tap cut in a main line can allow cement to flow inside the main line during installation and cause problems in the future (Figs. 7.3 and 7.4). Cracks, holes or pipe broken at a tap allow root intrusion, infiltration, and exfiltration.

7.143 Damage by the Public or Other Utility Agencies

Other utility agencies or the public can cause damage by underground construction, illegal taps or vandalism. Figures 7.5 and 7.6 show drain pipes from yard and gutters installed by a homeowner. Other agencies can run lines and ducts through sewer lines. Borings for foundation tests can penetrate sewer lines. Also telephone pole and guy wire augers can damage sewers.

7.15 Work Request Form

Upon discovery of a sewer line needing repair, a work request form should be completed (Fig. 7.7). Information on the form is essential for establishing repair priorities and scheduling work. The work request form should provide the following information:

1. Name of crew chief,
2. Date,
3. Street address near requested repair,
4. Map location,
5. Manhole numbers on each side of damaged pipe,
6. Size of pipe,
7. Depth of pipe,
8. Distance from both upstream and downstream manholes to damaged pipe,
9. Location of pipe (street or easement),
10. Work requested, and
11. Sketch of site with a North arrow.

6. [illegible]
7. Five feet, six [illegible]
8 Seven feet, [illegible]
9. Sierra View Way
10. Fix!

7.16 Assignment of Repair Job

When the repair or construction supervisor (maintenance supervisor) receives the work order form, the supervisor reviews the job and assigns it to a foreman or crew leader. If work loads are heavy, the foreman may assign a priority to work orders. Those repairs that are not urgent may be given a low priority and the work is done at a later date. When a foreman is assigned a work order, the job should be evaluated and the crew prepared to accomplish the repair job.

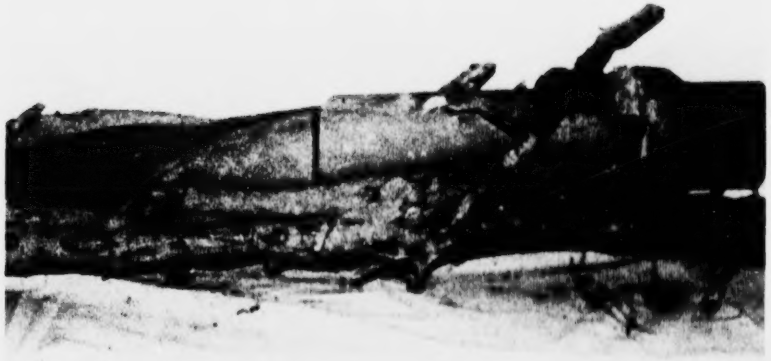


Fig. 7.1 Cracked pipe

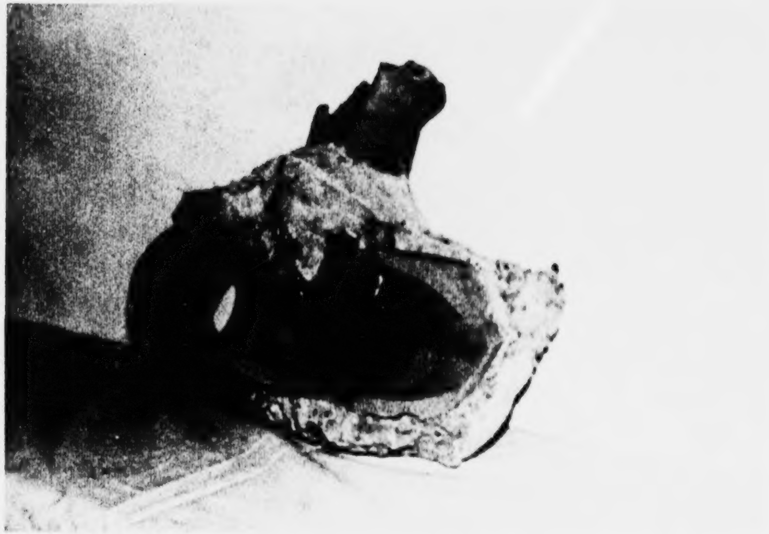


Fig. 7.2 Protruding tap

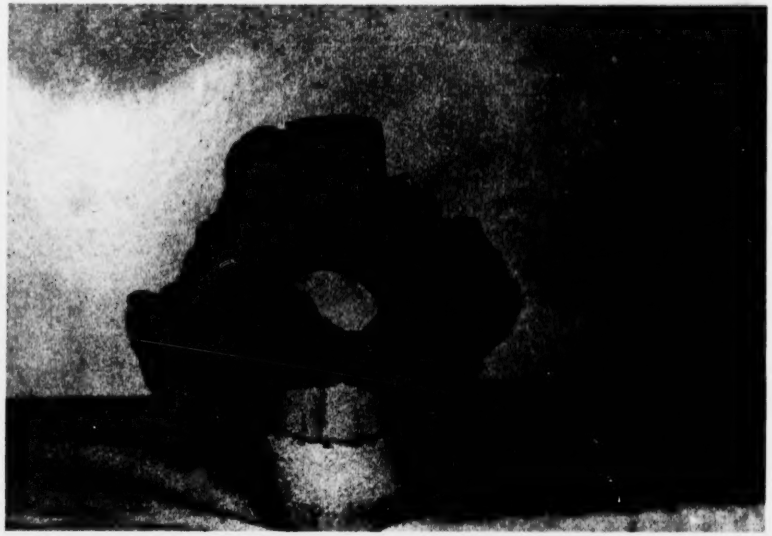


Fig. 7.3 Improper tap. Note cement in main line

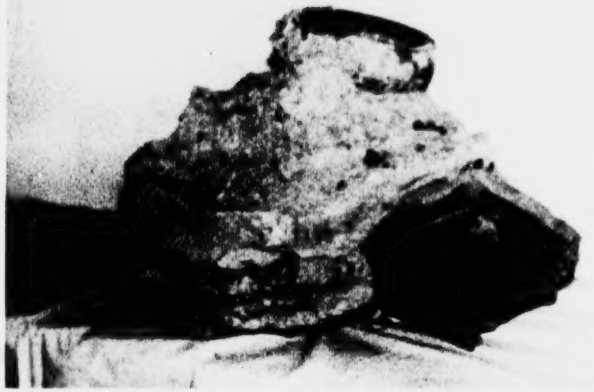


Fig. 7.4 Improper tap. Note cement poured around tap

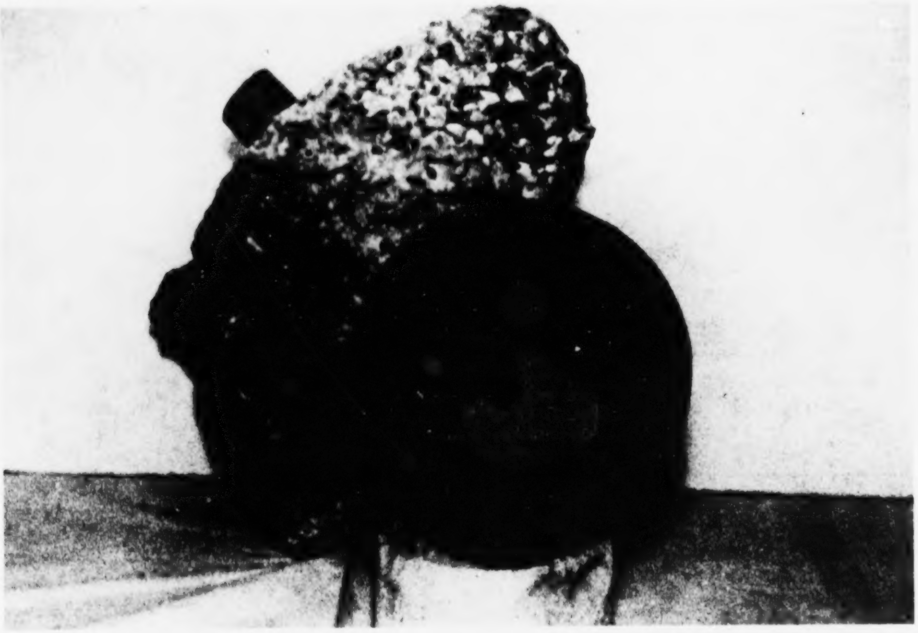


Fig. 7.5 Illegal drain tap

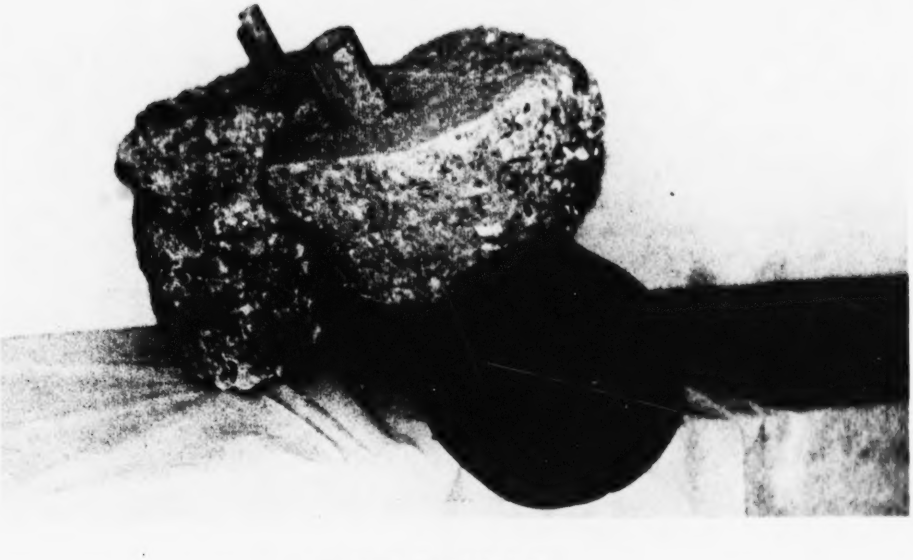


Fig. 7.6 Illegal drain tap

Crew Chief SWANSON Date 9-26-88
Address MARCONI AVE. Book 269 Page 05
Manhole 8 to 7
Pipe Size 6" VCP Depth 6'9" - 9'8" Distance 292
Street ☐ Easement ☒

Work Requested REPLACE TAP W/ROOTS

27' FROM M/H 8 → 7

PIC. #1

M/H 8 LOCATED AT 3609 MARCONI AVE.

Approved:

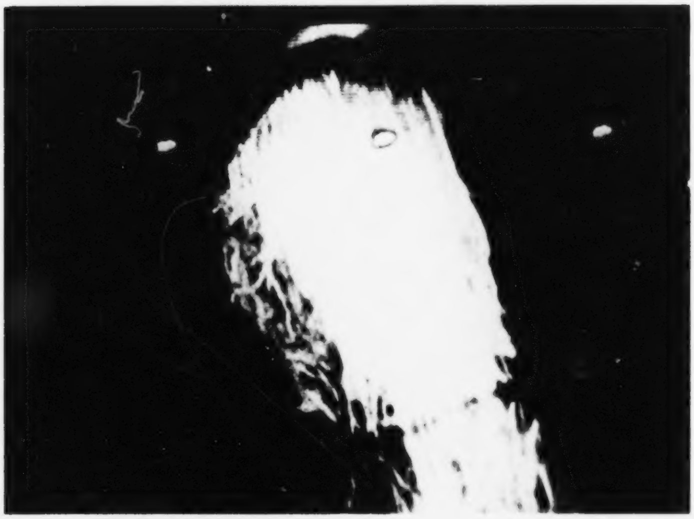


Fig. 7.7 Work request form and photo of roots in tap that must be removed and replaced

7.161 Investigate and Plan Job

Before starting a repair job, the foreman or supervisor in charge of the work should investigate the job site and plan the work. The foreman or supervisor should make notes on conflicts with utilities, traffic patterns, parked vehicles, or private property that might have to be moved, such as trees or fences, and soil conditions if known.

7.162 Meet with Utility Companies

All utility companies in the area should be contacted. Each company should meet the foreman at the job site and locate and mark utilities buried near the work area. Some underground utility companies are so small that their personnel cannot come out to the site and mark locations. If this occurs, inspect their maps in their office and do your own marking of the utilities. Utility companies will not accept responsibility for damage unless their personnel located their utilities. Most companies insist their personnel be on the job site until their facilities are uncovered and no conflict exists. When all underground utilities are located and marked, some thought should be given to overhead utility conflicts. The type of equipment used on the job depends on the potential problems encountered when doing the job.

7.163 Public Relations

Contact should always be made with the property owners in the area making them aware of any inconvenience that might occur. If excavation is going to block a drive-way into a business, contact the owner or manager and try to schedule your work so little or no conflict will exist. Good public relations are very important and should be considered at all times.

7.164 Preconstruction Meeting

A tail gate safety and preconstruction meeting should be held with all operators on the project (Fig. 7.8). Discuss what is to be accomplished and the duties of each person. What is to be accomplished means telling the crew what repair is necessary, such as a tap replacement, cleanout installation, or main line repair. The duties of each person will be the usual work assignment, unless special tools or materials are required for the specific job assignment. The preconstruction discussion is on what to expect and what to do if the unexpected occurs.

All safety regulations and work procedures for the particular job should be thoroughly explained. The notes taken by the foreman are valuable and should be used at this time. Operators' safety, pedestrian safety, and underground conflicts should be thoroughly reviewed so there will be no surprises when the crew arrives on the job site and starts to work. For more information, read Chapter 11, "Safety/Survival Programs for Collection System Operators" in Volume II.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 419.

7.1A Why are underground repair and new construction very hazardous?

7.1B Why is underground repair necessary?

7.1C How are underground damages discovered?

7.1D What are some causes of damages and stoppages that require underground repair?

7.1E What is the purpose of a work request form?

7.1F What should a foreman do before starting a repair job?

Fig. 7.8 Tail gate safety and preconstruction meeting

7.2 SHORING

Whenever excavation is necessary for repairs or new construction, shoring may be necessary to protect operators from cave-ins. The need for shoring and shoring requirements depends on many factors, such as, depth of trench, width of trench, type of soil (clay, loam, sand), soil conditions (compaction, moisture) and nearby activities that could cause vibrations. Other considerations when determining shoring requirements include the length of time the excavation is expected to be open. If an excavation is going to be open for an extended period, you would want heavier bracing to provide additional protection against vibrations from traffic and rains that could cause flooding. Shoring requirements are dictated by laws and codes and are strictly enforced by the regulatory agencies. Lack of shoring or shoring failure are the major causes of underground construction deaths. For example, seven people died and there were 67 lost-time injuries related to construction shoring problems in California during one year. By comparison, there were no deaths and 203 lost-time injuries to operators in the wastewater collection field during this same time period. How can we prevent these accidents? First learn the shoring laws and codes, types of shoring, proper use, and then apply this knowledge. Also develop a safety program and an approved OSHA (Occupational Safety and Health Act) shoring class. The Williams-Steiger Occupational Safety and Health Act (OSHA) of 1970 contains shoring regulations, and they are strictly enforced. Penalties for violating the regulations include warnings, fines and even prison sentences for flagrant violations. Contact your local safety office for all regulations pertaining to any excavations done by you or your crews. For additional information, read Chapter 3, Section 3.70, Excavation and Shoring, and Chapter 11, Section 11.2, 12. Excavation and Trench Shoring.

"SAFETY PROGRAM
"APPROVED OSHA SHORING
"REGULATIONS

7.21 Shoring Requirements

Typical shoring requirements include:

1. Shoring systems in trenches shall consist of uprights held rigidly opposite each other against the trench walls by jacks or horizontal cross members (cross braces) and, if required, longitudinal members (stringers) as hereinafter provided. Uprights shall not exceed 15 degrees from the vertical.
2. Uprights in trenches over 10 feet deep shall be not less than 3-inch by 8-inch material, and shall be at least 2-inch by 8-inch material in trenches less than 10 feet deep. (See Table 7.2 on page 302 for additional details and for requirements applying to running ground).

   Uprights shall extend from above the top of the trench to as near the bottom as permitted by the material being installed, but not more than 2 feet from the bottom.
3. Cross braces shall consist of steel screw-type trench jacks with a foot or base plate on each end of pipe or timbers placed horizontally and bearing firmly against uprights or stringers. Wood braces shall be no smaller than those listed in Table 7.1.

TABLE 7.1 SIZES OF WOOD AND PIPE BRACES IN TRENCHES[a]

Width of Trench, Feet (Incl.)	Size of Wood Braces	Size of Pipe Braces	Aluminum Hydraulic Shores
1-3	4"×4"	1½ "STD	2"
3-6	4"×6"	2" STD	2"
6-8	6"×6"	2" STD	2"
8-10	6"×8"	3" STD	2"
10-12	8"×8"	3" STD	3"

Wider trenches shall have cross braces of correspondingly larger dimensions.

[a] Consult with your local safety agency, for sizes of wood and pipe cross braces required in your area.

NOTE: In lieu of the above shoring systems, the use of properly maintained screw-type metal jack trench shoring units with equivalent strength is acceptable (Fig. 7.9).

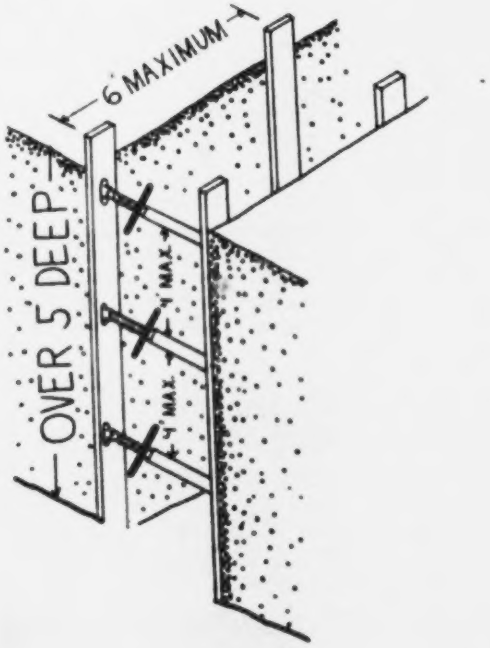


Fig. 7.9 Use of screw-type metal jack trench shoring units

4. The minimum number of horizontal cross braces, either screw jacks or timbers, required for each pair of uprights shall be determined by the number of 4-foot zones or segments into which the depth of trench may be divided. One horizontal cross brace shall be required for each of these zones, but in no case shall there be less than two cross braces or jacks. Trenches, the depths of which cannot be divided equally into these standard 4-foot zones or segments, shall have an extra horizontal cross brace supplied for the short remaining zone, if such zone is greater than two feet. In no case, however, shall the vertical spacing of horizontal cross braces be spaced greater than 5 feet center to center. Minor temporary shifting of horizontal cross bracing will be permitted, when necessary, for the lowering of materials into place. Be sure no one is allowed in the trench while the cross braces are temporarily shifted or moved. If the diameter of a pipe is greater than four feet, the lower cross braces require alternate considerations.
5. The dimensions and spacing of the elements of the shoring system shall be governed by the depth of the trench, type of soil encountered, and other special conditions of the site, but in no case shall they provide less strength than the members listed in Tables 7.1 and 7.2. These dimensions and spacings are to be considered as a minimum requirement.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 419.

7.2A Shoring requirements depend on what factors?

7.2B What is the number one cause of cave-in deaths?

7.2C What do shoring systems in trenches consist of?

7.2D Uprights shall extend how close to bottom of trench?

7.2E How is soil stability classified?

7.22 Responsibility

All excavation work shall at all times be under the immediate supervision of someone (such as a foreman or crew leader) with authority to modify the shoring system or work methods as necessary to provide greater safety. This person will frequently examine the material under excavation and improve the shoring or methods beyond the minimum requirements, as necessary to insure protection of operators from moving ground. Improved shoring or methods may be required if there is evidence of excessive shifting, displacement, or removal of cross bracing.

Someone must be on the job site and in charge at all times. This person not only accepts responsibility, but is authorized to change any predetermined shoring system when soil conditions change. Material handling, traffic pattern changes, public relations, repair work excavation, backfill and compaction are directed by the person in charge. Some of the listed jobs will have to be delegated or they won't be done effectively.

Tail gate safety meetings and the preconstruction meetings are very important. Everyone on the job site must know exactly what to do and what is expected to be accomplished.

7.23 Placing of Spoil[2]

For trenches less than five feet in depth, the spoil (excavated material) should be placed two feet or more back from the edge of the trench (Fig. 7.10). Trenches over five feet in depth should have the spoil placed four feet or more back from the edge of the trench. Try to keep the area between the trench and the spoil area clear of loose material. If not kept clear, material such as rocks, tools and pipe could be knocked into the excavation, or someone could trip on the equipment and fall into the trench. Keeping the area clear is not only good for the safety of operators, but reduces the chances of damage to new pipe or other conduits and utilities which could cause thousands of dollars worth of damages. Also keeping spoil away from the edge of the trench tends to reduce the load on the side walls, thus reducing the loads on the sheeting, uprights, stringers and cross bracing.

TABLE 7.2 DIMENSIONS AND SPACINGS OF ELEMENTS OF SHORING SYSTEM

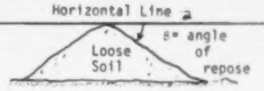
Soil Stability	Depth, Feet	Uprights: Size, Inches	Uprights: Horizontal Spacing, Feet	Cross Braces: Size, Inches	Cross Braces: Horizontal Space, Feet	Stringers: Size, Inches	Stringers: Vertical Spacing, Feet
Hard, compact	5-10	2×8	8	4×4	8	Where Indicated	
	Over 10	3×8	6	4×6	6	Where Indicated	
Unstable	5-10	2×8	4	4×4	4	Where Indicated	
		2×8	2	4×4	2	Where Indicated	
	Over 10	3×8	Solid	4×6	6	4×6	4
Running	4-8	2×8	Solid	4×4	6	4×6	4
	Over 8	3×8	Solid	6×6	6	6×6	4

Soil Stability may be classified as hard compact, running or unstable.

HARD COMPACT soil is all earth material not classified as running or unstable.

RUNNING soil is earth material whose angle of repose[a] is approximately zero, as in the case of soil in a nearly liquid state, or dry, unpacked sand which flows freely under slight pressure.

UNSTABLE soil is earth material that has a significant angle of repose, but because of vibration, moisture or other reasons, cannot be depended upon to remain in place without extra support.



[a] *Angle of repose. The angle between a horizontal line and the slope or surface of unsupported material such as gravel, sand or loose oil. Also called the natural slope.*

---

[2] *Spoil. Excavated material such as the soil from the trench of a sewer.*

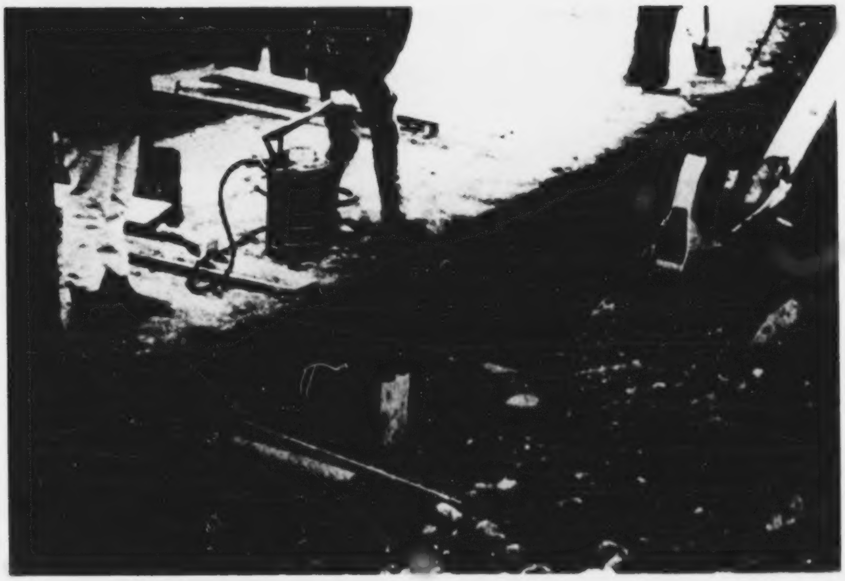


Fig. 7.10 Keep area near trench clear

This photo shows two unsafe conditions:

1. Shores do not extend above the ground surface, and
2. Spoil is too close to edge of trench.

7.24 Shoring Regulations[3]

7.241 Operator Safety

All trenches five feet in depth and deeper must be effectively shored to protect operators against the hazard of moving ground. Trenches less than five feet in depth also must be shored when examination indicates hazardous ground movement may be expected.

Special provisions must be made to prevent injury to operators engaging in installation of shoring. This may be done by providing and requiring the use of special devices such as long handled jacks that will allow upper cross braces to be placed from the ground surface before operators enter the trench. At those points in deep trenches requiring additional braces, operators shall then progress downward, protected by cross braces that have already been set firmly in place. Reverse procedure shall be followed when removing shoring.

7.242 Soil Conditions and Trench Location

The type of shoring installed depends on the soil conditions and the location of the trench. You cannot shore an excavation alongside a railroad track the same as one in an open area because of vibrations created by passing trains (Fig. 7.11). When the decision is made on the type of shoring to use, remember soil conditions change and an alternate shoring system should be readily available so little work time will be lost if a change must be made.

7.243 Sloping Excavation Walls

In lieu of a shoring system, the sides or walls of an excavation may be sloped if this method is considered more economical and the job can be done safely. Where sloping is a substitute for shoring, that would otherwise be needed, excavation side walls should be on a slope of ¾ foot horizontal to one foot vertical except where the instability of material requires a slope of greater than ¾ :1 (¾ vertical to 1 horizontal).[4] Read Chapter 3, Section 3.702, Trench Shoring, for more details.

7.244 Access to Construction Work Area

Convenient and safe means must be provided for operators to enter and leave the excavated area. Access shall consist of a standard stairway, ladder or ramp securely fastened in place at suitably guarded or protected locations where people are working. Ladders usually are less than 100 feet apart.

7.245 Pedestrian Safety

When working near curbs and sidewalks, keep a pedestrian way open on the sidewalks. If this area becomes covered with material and equipment, the pedestrians will be in the work area or walking across someone's yard. Neither one of these situations is acceptable. If necessary, erect barriers to keep pedestrians and children in safe, permissible areas. Be especially careful if children are playing or watching near the job site.

---

[3] *These regulations are from the State of California's Division of Industrial Safety, Construction Safety Orders, Title 8, Subchapter 4, Article 6. Other states have similar regulations. You should contact your state industrial safety officer to obtain the shoring regulations for your state.*

[4] *Slope of ¾ :1.*

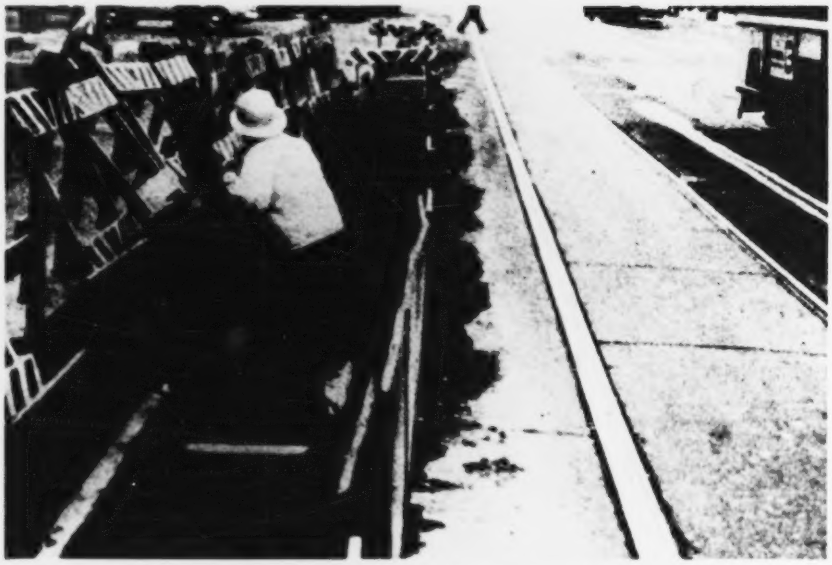


Fig. 7.11 Shoring alongside a railroad track

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 419.

7.2F What should be the authority of someone supervising excavation work?

7.2G Where should spoils or excavated material be placed?

7.2H All trenches deeper than ______ feet must be shored.

7.2I How can operators be protected if shoring is not practical?

7.2J Why must a walkway be provided for pedestrians?

7.25 Types of Shores

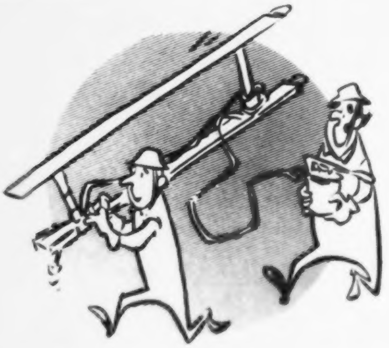
There are several types of shores that have been tested and approved by OSHA. Each type of shoring has its good and bad points. Selection of types of shoring depends largely on soil conditions in your area.

7.251 Hydraulic Shores

Hydraulic shores are used frequently due to their ease of installation and removal. They are usually not used on jobs when they will be required to be left installed in one segment of trench for a time period greater than five days due to the possibility of the hydraulic pressure bleeding off during a longer period of installation.

The standard aluminum hydraulic cylinder (Fig. 7.12) is 2 inches in diameter. Each shore has two cylinders and two 7-foot rails equal in strength to 3"×10" timbers. Each rail is 8 inches wide and 1½ inches deep. The complete unit weighs 70 pounds and can spot-brace trenches 22 to 48 inches wide. The two cylinders are connected by a high-pressure, flexible hose that allows fluid to be pumped into the cylinders to expand them to the desired length (Fig. 7.13). Recommended fluid to use in hydraulic shores is one quart shoring fluid (water soluble oil) to 19 quarts water for each five gallon mixture.

Never use plain water without shoring fluid. The shoring fluid acts as a lubricant, protects the shores from corrosion damage and mineral deposits, and lowers the freezing point of the liquid mixture. Always follow shoring fluid manufacturer's recommendations.



Installation of the standard hydraulic shore is usually a one operator job. Place shore across trench with one rail on top of the other in the trench. Connect pump hose to male fitting on shore (top cylinder). Open valve on pump. The installation tool (Fig. 7.14) is from 30 to 96 inches long depending on depth of trench in which you are installing the shores. This tool is approximately a one-half inch diameter steel rod with a tee handle on one end, a hook and pressure release on the other end. This tool is hooked on to the side rail of the shore and held firmly with the other hand, grasp handle on the opposite side rail and lower shore into trench. When desired position of shore is reached, close valve on pump and start pumping by raising and lowering pump handle (Fig. 7.15). When desired pressure is reached, usually 750 to 1000 pounds per square inch, disconnect hose from cylinder by using lower end of installation tool. Open valve on pump to relieve pressure in hose. Coil hose around pump to keep connecting end free of dirt and sand. Move pump to next installation and repeat the procedure at the prescribed intervals shown in Table 7.2, page 376.

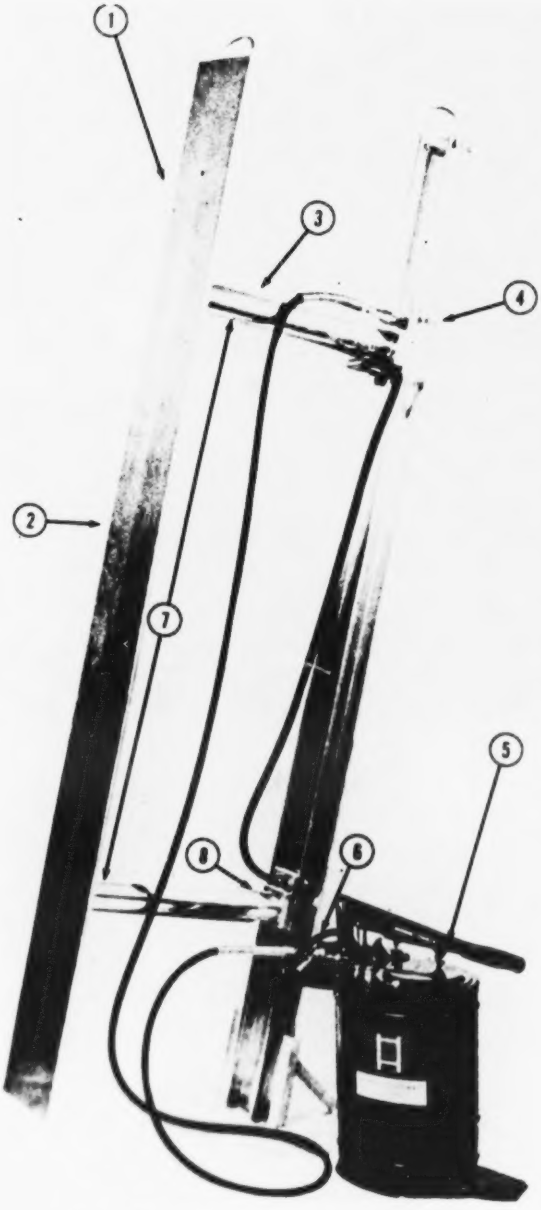


Fig. 7.12 Aluminum hydraulic cylinder
(Courtesy of SPEED-SHORE)

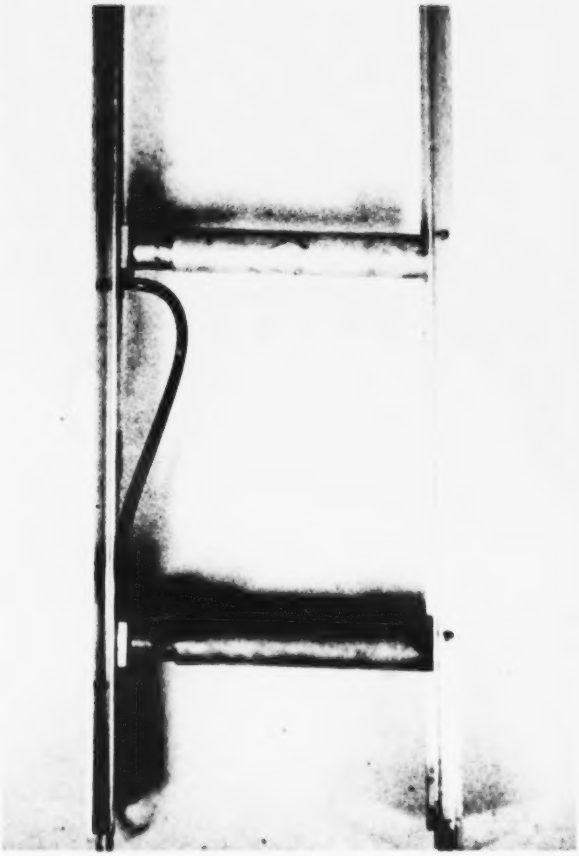
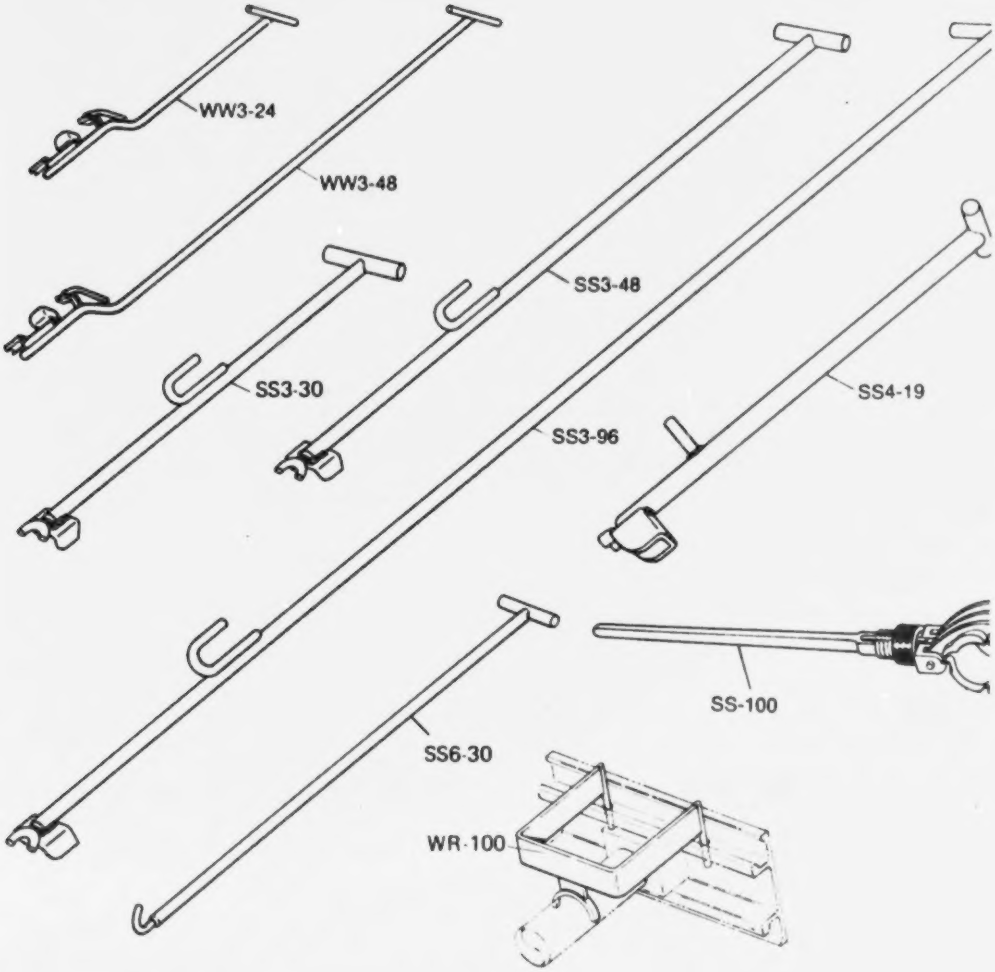


Fig. 7.13 Aluminum hydraulic cylinder and pressure hose

1. Aluminum alloy material
2. Flanged siderail
3. Hydraulic cylinder
4. Offset pins connecting siderails and hydraulic cylinders
5. Pump
6. Pressure gage
7. 4-foot cylinder spacing
8. Cylinder pad



SPEED SHORE ACCESSORY PARTS LIST

Part No	Description	Part No	Description
SS3-30	Speed Shore Release Tool 30" (76.2 CM)	SS6-96	Removal Hook [illegible]*
SS3-48	Speed Shore Release Tool 48" (121.9 CM)	WW3-24	Water Release Tool [illegible]
SS3-96	Speed Shore Release Tool 96" (243.8 CM)	WW3-48	Water Release Tool [illegible]
SS4-19	Single Shore Release Tool 19" (48.2 CM)	SS-100	Speed Shore [illegible]
SS6-30	Removal Hook 30" (76.2 CM)	WR-100	Water Rack
SS6-48	Removal Hook 48" (121.9 CM)*		

* Not pictured

PRINTED IN U.S.A.

Fig. 7.14 Installation and release tools
(Courtesy of SPEED-SHORE)

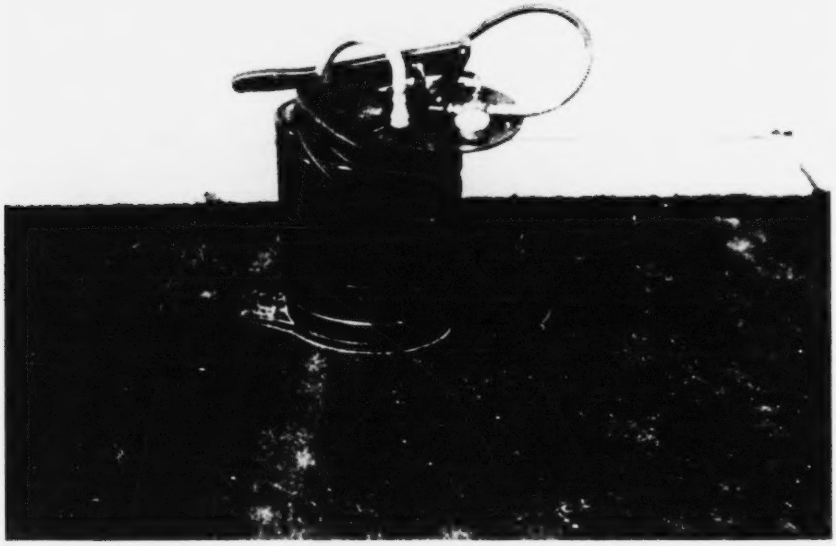


Fig. 7.15 Pump for hydraulic cylinder
(See Fig. 7.12, item 5, pump)

The two-inch cylinder can be reinforced with square steel tubing and extensions used to shore trenches up to 14-feet wide. For excavations from 10 feet up to 24 feet in width, the three-inch aluminum hydraulic cylinder is used. If you do not have experience shoring trenches 10 feet and wider, obtain correct information and engineering advice before starting the project. Improper shoring materials can be very costly on trenches or excavations of this size.

7.252 Screw Jacks

Screw jacks (Fig. 7.16) are time consuming to install and usually are not used on large production jobs. They are inexpensive to purchase; and for minor repairs in smaller excavations, they are more practical than other types of shores. Screw jacks must be placed from top down, and those who have used them know this is a slow process. Screw jacks

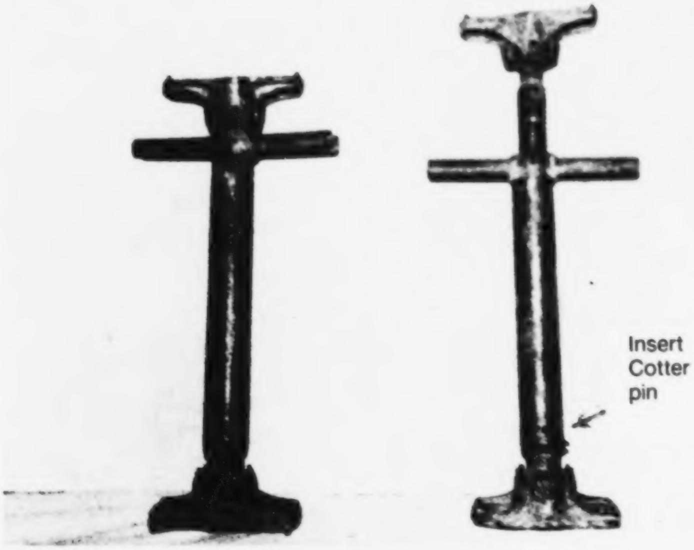


Fig. 7.16 Screw jacks

414

are made of iron and come in two pieces. They are available with a 1½ or 2-inch threaded shaft and wing nut that is used for adjustment to fit trench width. One end of the shaft is plain and the other has a ball-socket for a shoe that goes against the shoring. The screw length on the 1½ inch shaft varies from 10 to 18 inches. The 2-inch shaft has a screw length of 18 inches only.

The other part of the screw jack consists of a shoe and ball joint with a male fitting to fit inside a 2-inch pipe. This fitting has a hole to secure the desired length of pipe to it. Cut the length of pipe required, usually about 8 inches shorter than the trench width. Drill a hole through one end large enough to accept a cotter pin. All jacks should be assembled before excavation is started. Extra pipe should be available if needed. The weight of each jack varies from 13 to 23 pounds, depending on length of pipe used. Installation of the screw jacks usually requires two operators. The hydraulic jacks have rails for the cylinders to push against. The screw jacks have none, so timbers must be used (Fig. 7.17). Vertical members of the shoring in trenches less than 10 feet deep use a minimum of 2 × 8 rough timbers. In trenches over 10 feet deep, use a minimum of 3 × 8 rough timbers. Timbers should be Douglas Fir or equal. Always use full cut and rough dimension timbers. See Table 7.2, page 302, for additional details and requirements applying to "running" soil conditions.

Two operators are needed to install screw jacks. One operator holds the vertical timbers and the other installs the screw jacks. Begin installing screw jacks at the top of the trench and no more than two feet down from top. The first jack is placed in the trench and the wing nut screwed out against the pipe until enough pressure is applied to hold the timbers in place (Fig. 7.18). When installing jacks from top to bottom, the upper jacks tend to loosen up; and if they are not secured with a nail, they might fall on the operator installing the bottom jack. When all the jacks are in place, tighten them until the vertical timbers (uprights) are flush against the walls of the trench (Fig. 7.19). Each jack should be pushed against the uprights with a similar force. Good judgement must be used to determine when screw jacks are tight enough.

7.253 Air Shores

Air shores (Fig. 7.20) are new by comparison to the other shores discussed. They are a pneumatic shoring cross brace made for trenches where shoring is required.

Air shores are not equipped with rails like hydraulic shores. They are used similarly to screw jacks and are used only as the cross brace which can be rapidly set to hold shoring members in place.

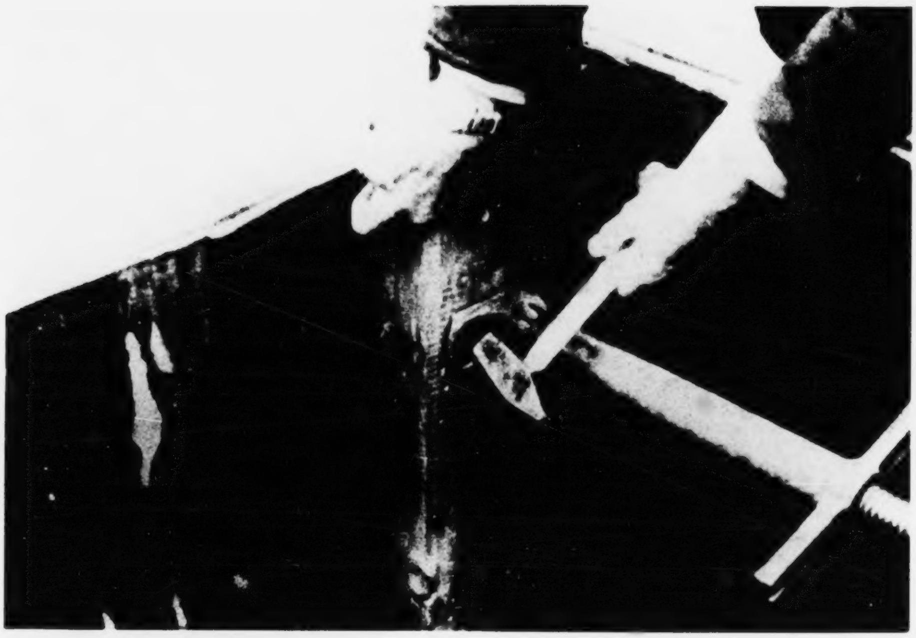
Five sizes of air shores are designed for various trench widths and excavations. The 18 to 27-inch span air shore weighs ten pounds.

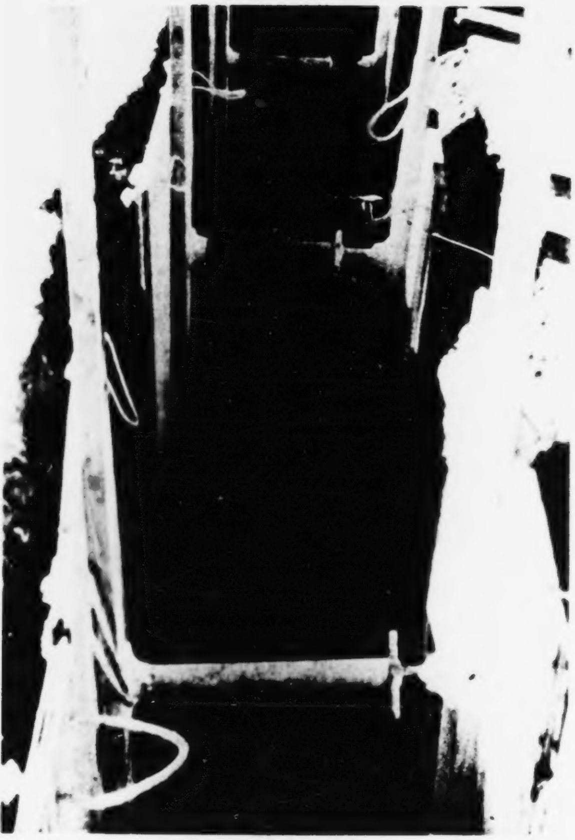
The largest air shore has a 60 to 96-inch span and weighs 30 pounds. Air shores are activated or expanded by compressed carbon dioxide (CO_2) gas.

To install or remove air shores requires two operators. One or two additional operators are needed to hold the sheets and braces in place on each side of the trench while the air shore is being installed. The shore is held in place or positioned by one operator. The other person actuates the carbon dioxide valve and expands the air shore ram against the shoring to a pressure of 200 to 300 psi. When the shore has been expanded, the operator positioning the air shore rotates the locking collar and inserts a pin behind the locking collar and through the ram to form a mechanical lock. The carbon dioxide is then bled off from the ram and the air shore becomes a mechanical brace.

Fig. 7.17 Screw jacks with timber uprights

WARNING — Never use jacks for access ladders. Always use a ladder.





To release the air shore, carbon dioxide gas pressure is applied to the air shore until the ram expands enough to remove the locking pin. Next the carbon dioxide pressure is reduced until the shore is free and can be removed along with the sheeting or timbers used to shore the trench.

7.254 Solid Sheeting

Occasionally excavation is necessary in materials that will not stand vertical and, because of the location, it is not practical to slope the trench. Under these circumstances you must use a solid sheeting method (Fig. 7.21). Timbers used in this method must be fully dimensional rough cut timbers. Minimum sizes are 2 × 8 inch rough timbers for trenches up to 8 feet deep and 3 × 8 inch rough timber for trenches over 8 feet deep. Metal plates can be used as solid sheeting if properly engineered. See Table 7.2, page 376, for additional details and requirements applying to "running" conditions.

The horizontal shoring members are generally referred to as "stringers" or "walers". When purchasing shoring material, buy the square 6 × 6 rough timber (Fig. 7.22), or the 8 × 8 rough timber because finished dimensional timber is smaller and not as strong. Either hydraulic or air shores or screw jacks can be used as cross braces.

The same rule applies on placing the cross braces as in hard compacted materials, maximum allowable distance between cross braces is four feet. In material that requires solid sheets, the sheeting should be driven into the excavation bottom one foot or more and kept below the bottom of excavation as it goes down. All timbers used must be free from splits, large knots or loose knots. In some areas suitable timbers are extremely difficult to find. For this reason, metal sheeting may be better. Whether to rent or purchase shoring depends on expected needs and economics.

Fig. 7.19

Screw jacks holding vertical timbers or uprights against wall

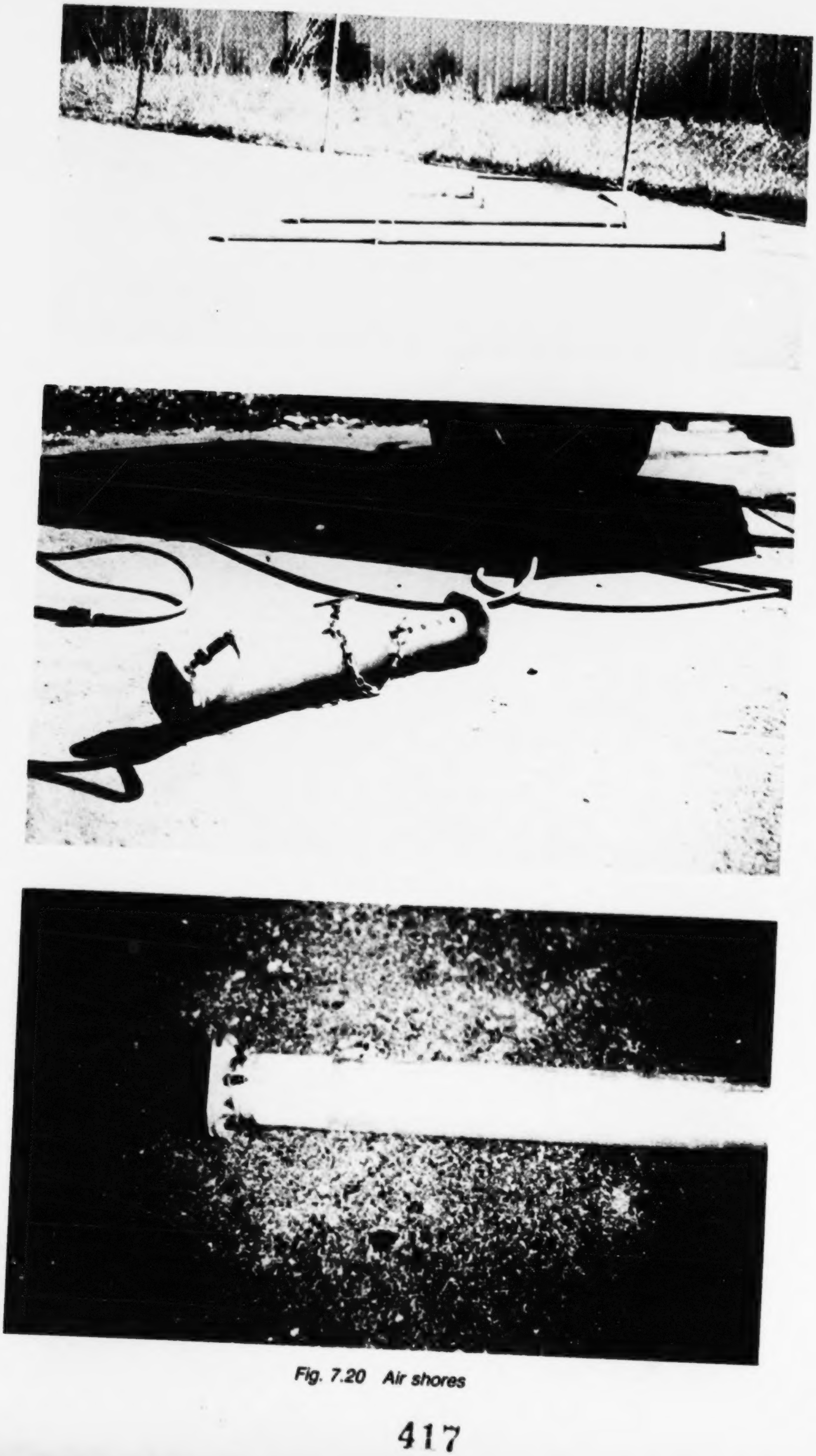
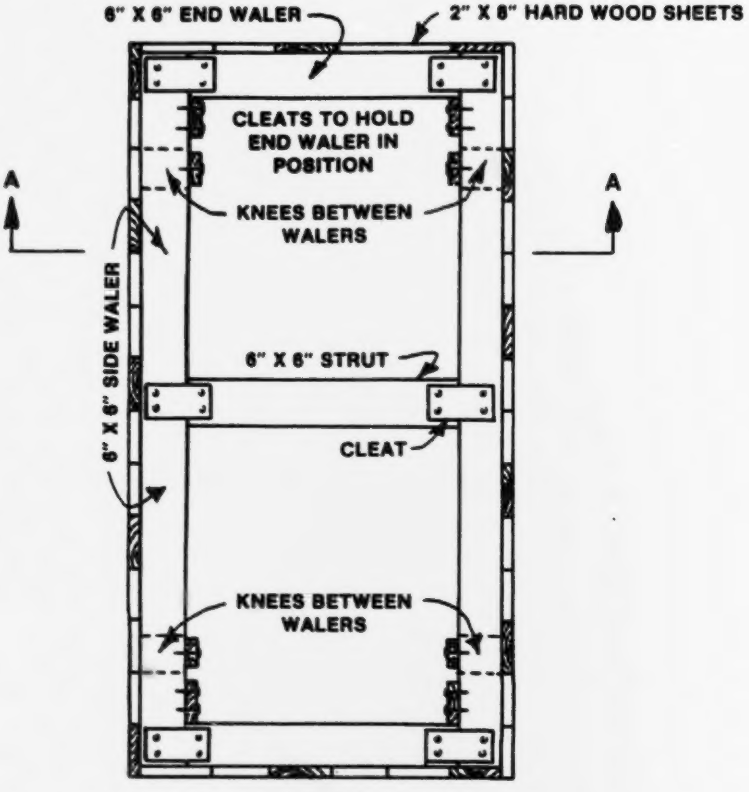
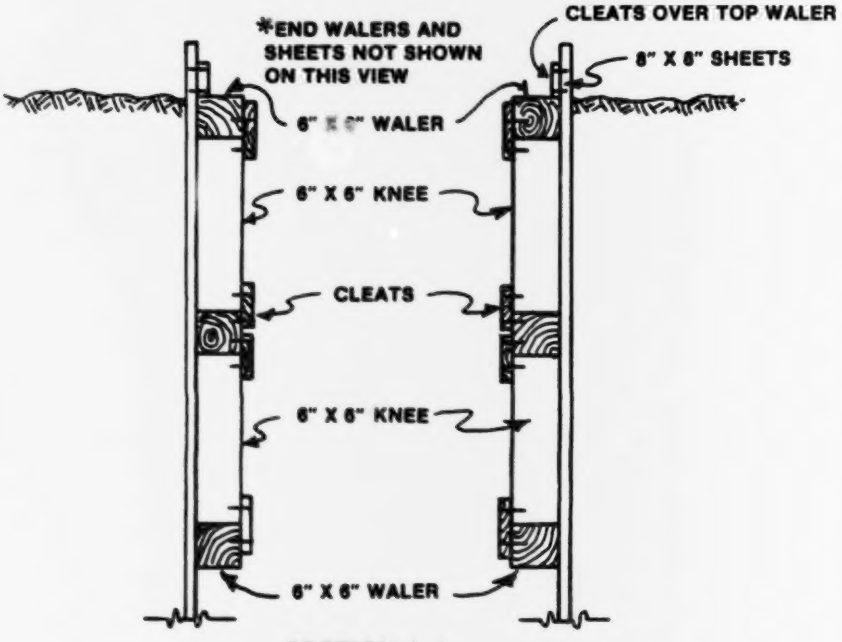


Fig. 7.20 Air shores


6" X 6" END WALER
2" X 8" HARD WOOD SHEETS
CLEATS TO HOLD END WALER IN POSITION
A
A
KNEES BETWEEN WALERS
6" X 6" SIDE WALER
6" X 6" STRUT
CLEAT
KNEES BETWEEN WALERS

PLAN


*END WALERS AND SHEETS NOT SHOWN ON THIS VIEW
CLEATS OVER TOP WALER
8" X 8" SHEETS
6" X 6" WALER
6" X 6" KNEE
CLEATS
6" X 6" KNEE
6" X 6" WALER

SECTION A-A

Fig. 7.21 Solid sheeting

STRINGER MATERIALS SHOULD BE IN THE SQUARE

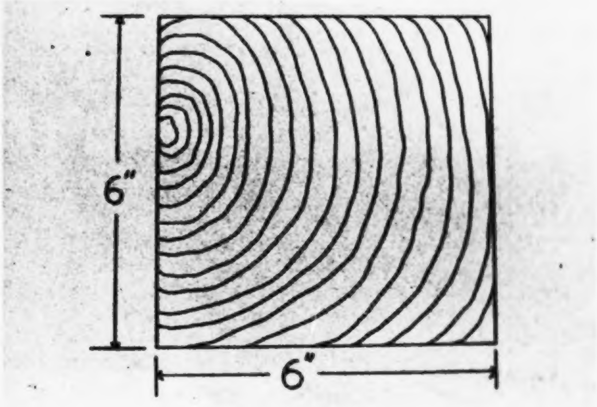


Fig. 7.22 Square 6 × 6 rough

7.255 Cylinder Shoring

Cylinder shoring can be made from ¼-inch or 5⁄16-inch thick steel plates that are four feet wide. These sheets are rolled into a cylinder with a four-foot inside diameter and four feet in height (Fig. 7.23). The top and bottom of each cylinder is reinforced with a welded angle iron rolled to fit the cylinders. Each cylinder section weighs either 550 (¼-inch plate) or 675 (5⁄16-inch plate) pounds. This weight usually limits the use of cylinder shoring to street locations or areas where cranes or hydro lifts can be used to position the cylinders. Cylinders four feet high and four feet in diameter are easy to transport and handle, but are confining on large jobs. Larger cylinders can be made and used to rebuild or construct a new manhole.

One end of each section of a cylinder is provided with three male alignment pins approximately two inches in diameter and spaced at one-third intervals around the bottom circumference of the cylinder. The top or opposite end of the cylinders has three holes to accept the male locking pins. As the cylinder sections are stacked on top of each other, the locking pins prevent rotation or slipping of the sections. The pins thus maintain vertical alignment and structural safety at the section connections. Two hooks are installed inside the cylinders to make moving the cylinders easier.

The excavation is usually started and dug as deep as practical within the safety limitations. The bottom of the hole is made as level as possible and the first cylinder is set in the hole. From here on down, it is all hand excavation. An operator and a ladder are put into the cylinder (Fig. 7.24) and a bucket and rope are used to move the spoil to the top of the ground. The cylinder is kept level as it goes down. When the proper depth is reached, another cylinder is set on the first one. This process is repeated until the excavation is completed.

Some agencies use square boxes instead of cylinders for shoring under these conditions. Another way to remove excavated soil from the inside of a cylinder or a box is to use a vacuum device like a Vac-All. Operators inside the cylinder loosen soil and guide it into the suction tube. This procedure works very well with dry soils and some wet soils. Problems develop when attempting to vacuum wet clays and any wet soil during freezing conditions because of freezing in the tube.

To reverse the procedure, backfill is dumped into the cylinders until about two feet of the bottom cylinder is filled and compacted. A chain is connected to the inside hooks of the bottom cylinder and all the cylinders are lifted up about two feet. Continue to add backfill in two foot layers, compact, and raise cylinder until bottom is at level of fill each time. Remove the top cylinder when the entire cylinder is raised to the level of the ground. Repeat this procedure of dumping fill into the remaining cylinders in two foot layers until all cylinders are raised to the ground level and the excavation is filled to grade.

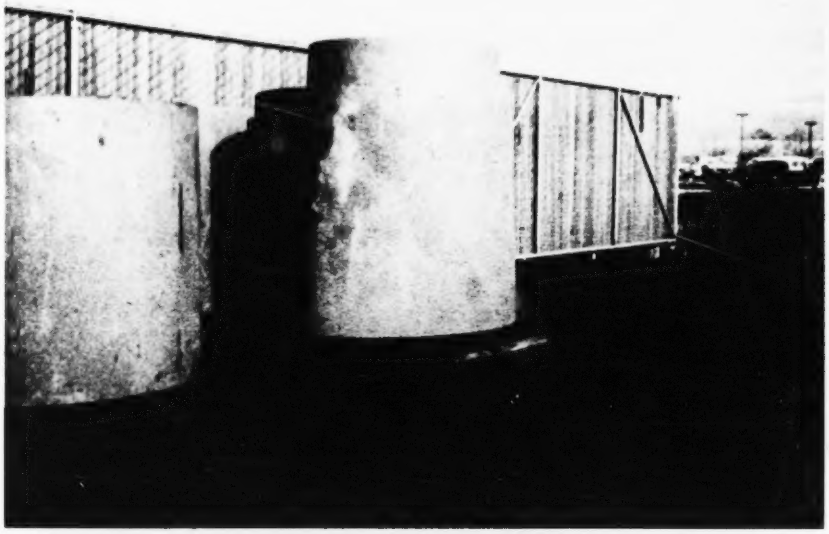


Fig. 7.23 Cylinder shoring

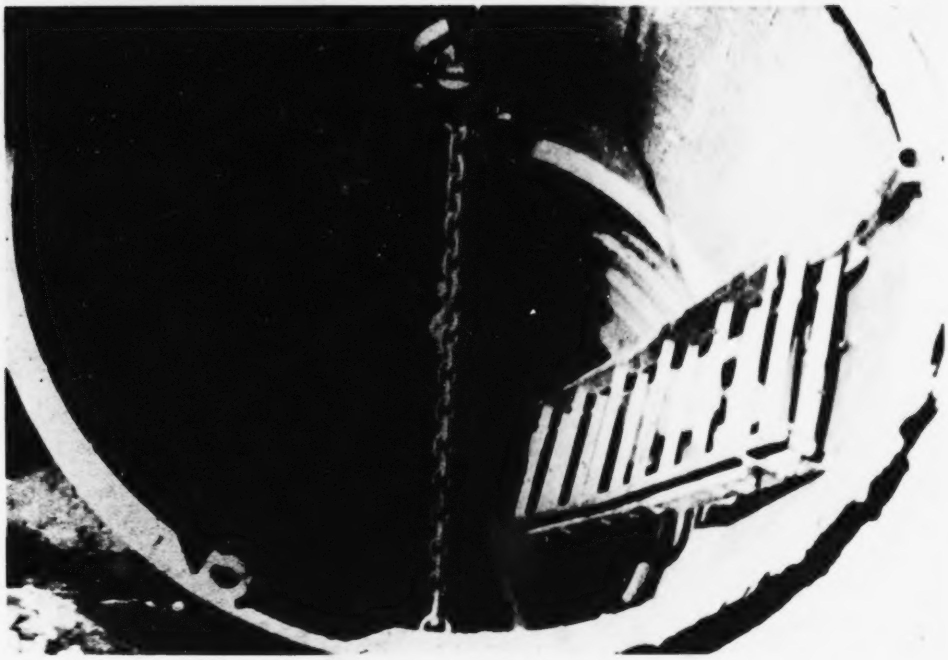
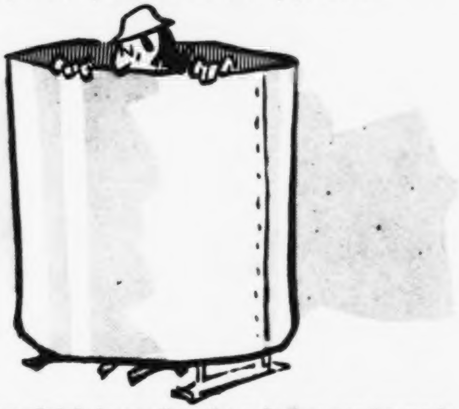


Fig. 7.24 Ladder inside cylinder

The cylinder method is time consuming, but requires less time than use of sheeting, uprights, stringers and cross bracing. A limitation is that only the inside diameter of the cylinder is the working area. This approach has been used to make a new connection or repair a small portion of a main line in areas where this method was the best technique. If the working area is small and only a small portion of the main line needs to be exposed, cylinders can be very practical.



A vertical bore slightly larger than the cylinders can be made if the soil is stable enough to hold until the cylinders can be placed in the hole. This procedure saves the time required for hand excavation and is much faster. Excavations as deep as 30 feet have been completed very successfully using this method.

7.256 Shield Shoring

Shield shoring (Fig. 7.25) is used during excavation and installation of various types of sewers in areas and soil conditions that present a combination of problems. Shield shoring consists of a rectangular box that must be opened on the top and bottom and usually the ends are open too. Size of shield depends on the size of sewer line being installed and the necessary space needed to install the pipe. Shields can vary in width from 30 inches to 10 feet and in length from 20 to 30 feet.

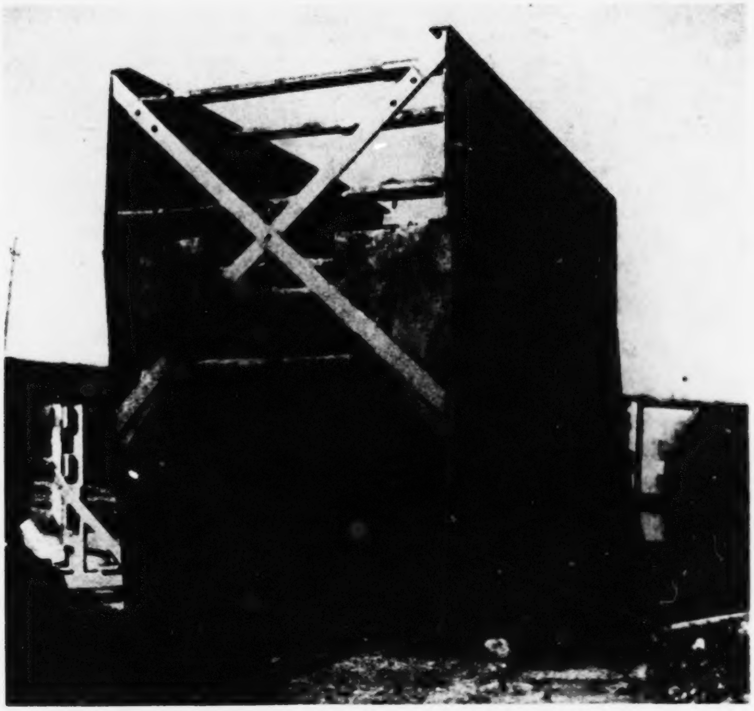
Another type of shield shoring is an adjustable box that can provide protection for either trench or manhole work. Boxes of this type are certified by their manufacturer for use within specified excavation depths and widths. These boxes are usually fabricated so two boxes may be stacked to increase working depth and are certified by the manufacturer for this use.

The City of Tacoma, Washington, has developed a shoring crib that was fabricated in their shop and can be installed in an excavation in less than 30 minutes. The following four pictures on pages 389 and 390 show how the crib is installed.

If the excavation is dug with a trencher, the shield is connected to the trencher and pulled along as the trench is dug (Fig. 7.26). Pipe is laid as the trench is completed. If a backhoe or other bucket type equipment is used to excavate the trench, the shield is stationary until a portion of the trench is dug; then it is hooked onto the excavation equipment and pulled into position.

Another type shield has hydraulic rams which expand and make the rectangular box longer or contract to make it smaller. The purpose of the rams is to move the shield with its own power. In the expanded position, pipe is bedded and laid; then the rams are contracted and backfill placed behind the shield. The rams are then expanded and force the shield ahead.

The initial cost for any shield is very expensive, but often may be cheaper than solid sheeting in the long run.



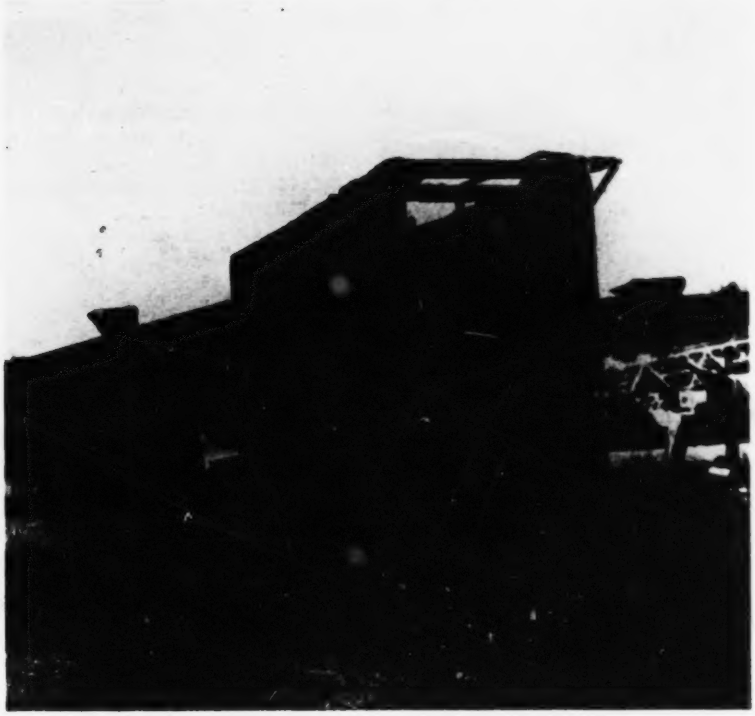


Fig. 7.25 Shield shoring

1. Dig trench.

2. Insert crib.

424

3. Install sheeting.

425

4. Shoring completed.

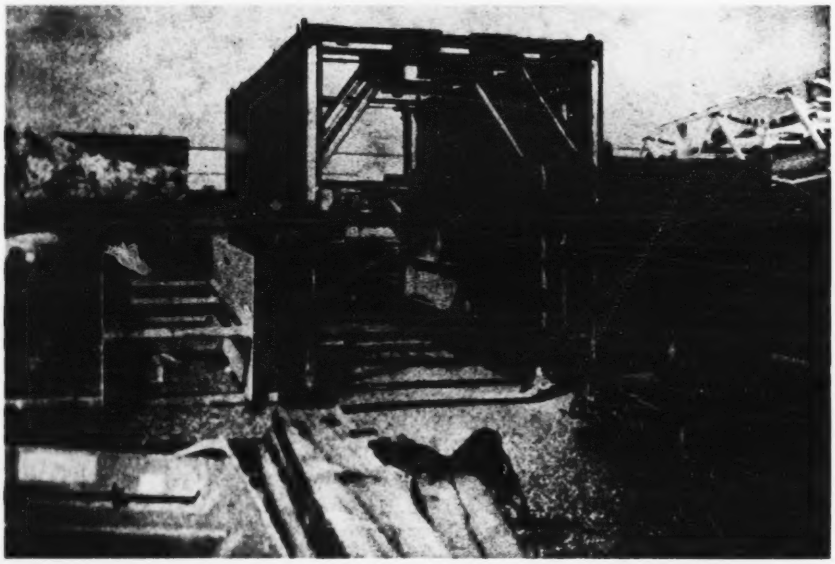


Fig. 7.25 Shield shoring

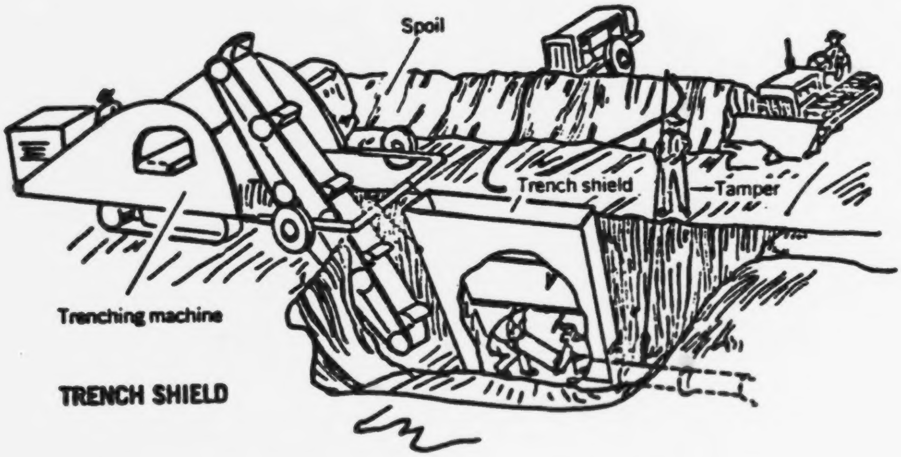


Fig. 7.26 Trench shield being pulled by trenching machine

7.26 Shoring Summary

This section has identified the common shores and their uses. Selection of shores depends on several factors and the job you are trying to accomplish.

PROTECT YOUR OPERATORS AT ALL COST. Attend all trench safety lectures and seminars. Contact your own safety council and see what information is available and what is required. Be sure that everyone complies with all regulations. *ALL TRENCHES AND EXCAVATIONS ARE UNSAFE UNTIL PROPERLY SHORED, USED AND BACKFILLED (FIG. 7.27).*

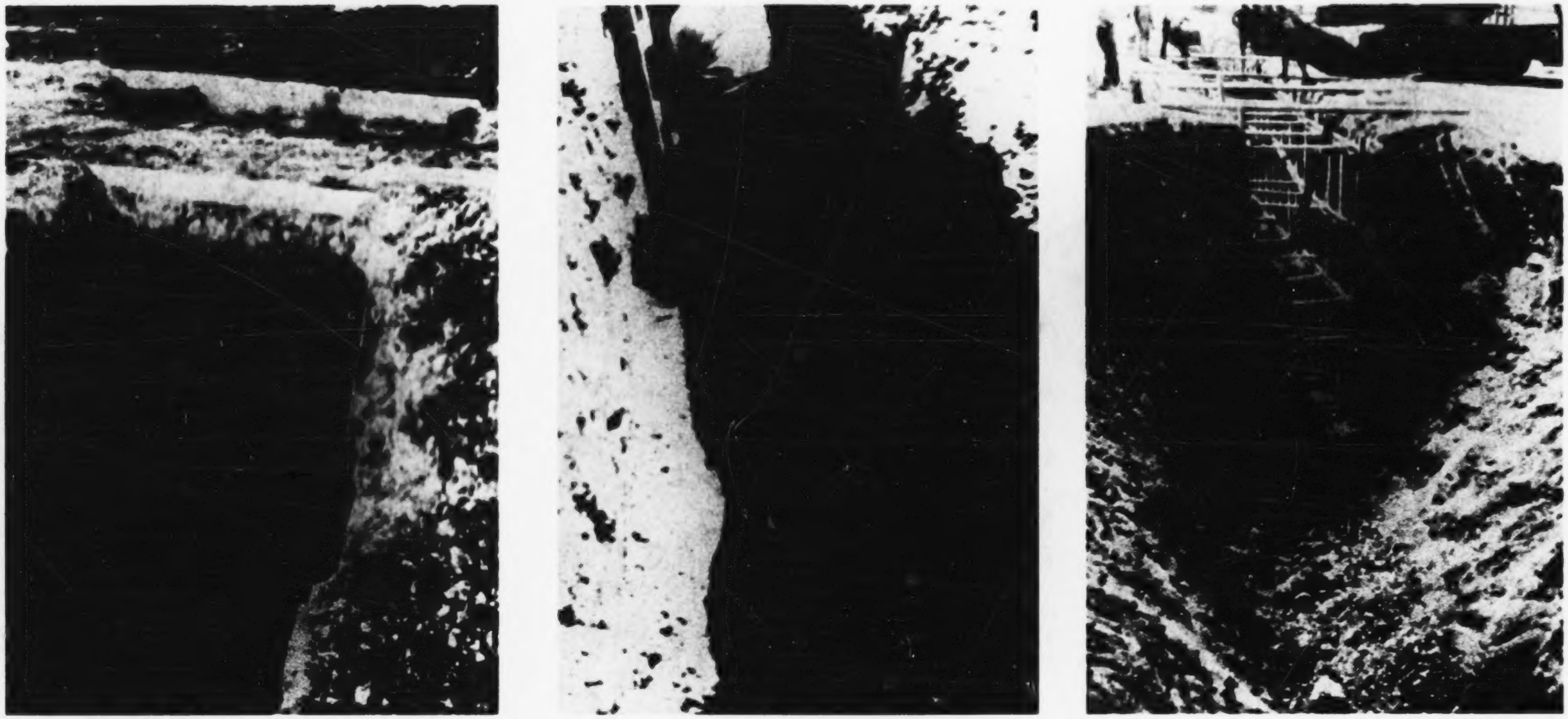


Fig. 7.27 All trenches are UNSAFE until properly shored, used and backfilled

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 419.

7.2K List the different types of common shores.

7.2L What are the main advantages of hydraulic shores.

7.2M What are the main advantages and limitations of screw jacks?

7.2N When must solid sheeting be installed?

7.2O How is material excavated in cylinder shoring?

7.2P When is cylinder shoring used?

7.2Q Under what conditions is shield shoring used?

7.2R What is the major concern during a shoring operation?

END OF LESSON
1 OF 3 LESSONS
ON UNDERGROUND
REPAIR

DISCUSSION AND REVIEW QUESTIONS

Chapter 7. UNDERGROUND REPAIR

(Lesson 1 of 3 Lessons)

At the end of each lesson in this chapter you will find some discussion and review questions that you should answer before continuing. The purpose of these questions is to indicate to you how well you understand the material in the lesson. Write the answers to these questions in your notebook before continuing.

1. What safety items must be considered when excavation is required to repair a sewer located in a street?
2. Why might a sewer line have to be dug up?
3. Why should other utility companies be notified before any excavation?
4. How can operators in trenches be protected from cave-ins?
5. How can you determine the shoring requirements in your area?
6. What are the different types of shoring and the advantages and limitations of each type?

CHAPTER 7. UNDERGROUND REPAIR

(Lesson 2 of 3 Lessons)

7.3 REPAIR OF SERVICE LINES

Building or house service lines must be repaired when the lines develop stoppages or leaks. Repair crews are notified of a repair job when they receive a work order form from their supervisor. Repair assignments must be made in writing in order to maintain records and provide a history of who made what repairs when, where, how and why.

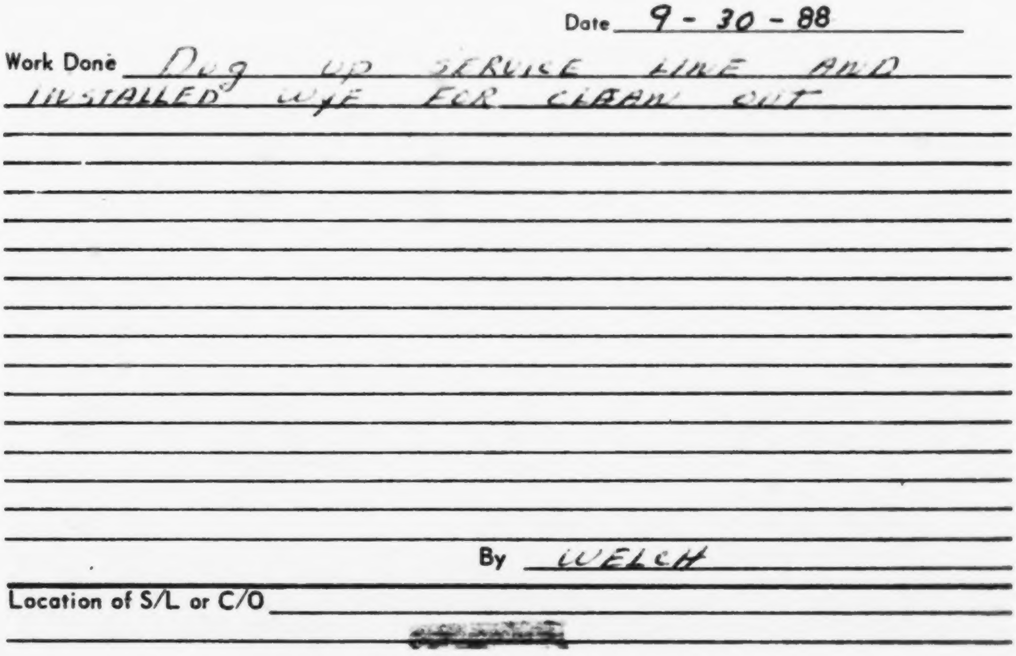
This section describes the steps to follow in order to respond to a work order request (Fig. 7.28) to install a cleanout. A cleanout was required in this example because one was not installed when the sewer was built and the cleanout is needed to help when clearing a reoccurring root problem.

7.31 Preliminary Investigation

Upon receipt of a work order request, existing records are examined to determine if the problem has occurred in the past. Existing records may indicate the types of problems and soil conditions the repair crew could encounter in the field.

A foreman makes a preliminary field investigation and alerts the property owner that a crew will be digging in the yard to repair the problem sewer. A brief explanation of the job to be done is good public relations, such as how much digging will be done and where in order to install a cleanout and/or replace a faulty section of sewer. The foreman also looks for potential problems so the foreman can alert the crew leader (Maintenance Man II) of any usual problems that may exist. Helpful information includes large shrubs that have to be removed or flowers and shrubs that have to be transplanted. Utility companies must be contacted and requested to locate their utilities in the vicinity of any excavation. Take photographs of work areas on private property *BEFORE* starting to work. These photographs can be very helpful if any legal claims develop regarding cracked sidewalks and foundations or damaged lawns and fences.

After the preliminary investigations, the work order request is given to a repair crew.



Date 9 - 30 - 88

Work Done Dug up SERVICE LINE AND INSTALLED WYE FOR CLEAN OUT

By WELCH

Location of S/L or C/O [redacted]

Fig. 7.28 Work order request to install a cleanout

7.32 Job Assignment to Repair Crew

After receiving the work order request from the foreman, the crew leader and foreman discuss the job. How to meet safety requirements and what materials will be needed are reviewed.

The crew leader has the responsibility to inspect the personal safety equipment of the crew. Inspection must include examination of steel toed boots, hard hats, gloves and safety glasses (Fig. 7.29).

7.33 Equipment, Materials and Tools

Proper tools, equipment and materials to do the job must be on the repair crew's truck before they drive to the job site.

Material usually required for sewer repair and cleanout installation include sections of 4-inch pipe, 4-inch wyes with main barrel ranging in length from 16 to 22 inches, ⅛ bends or 45° elbows, 4-inch couplings, 4-inch bushings, and plastic plugs (Fig. 7.30).

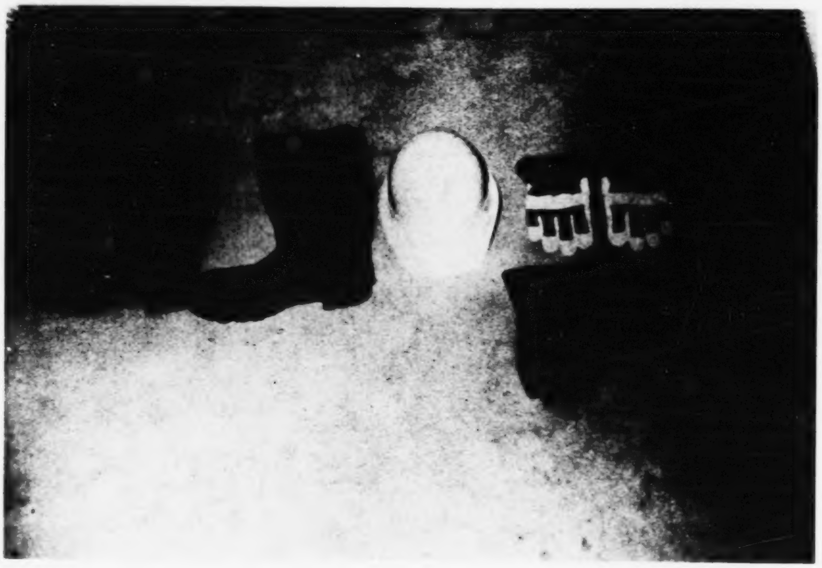


Fig. 7.29 Personal safety equipment

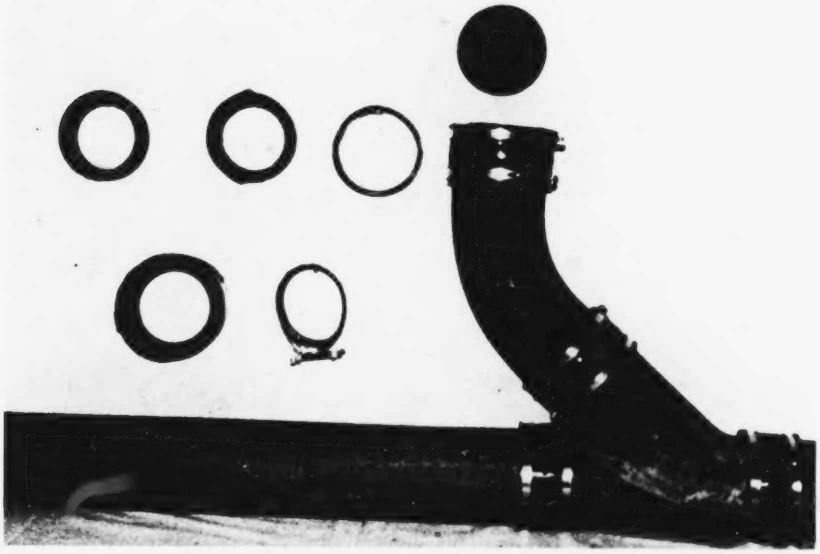
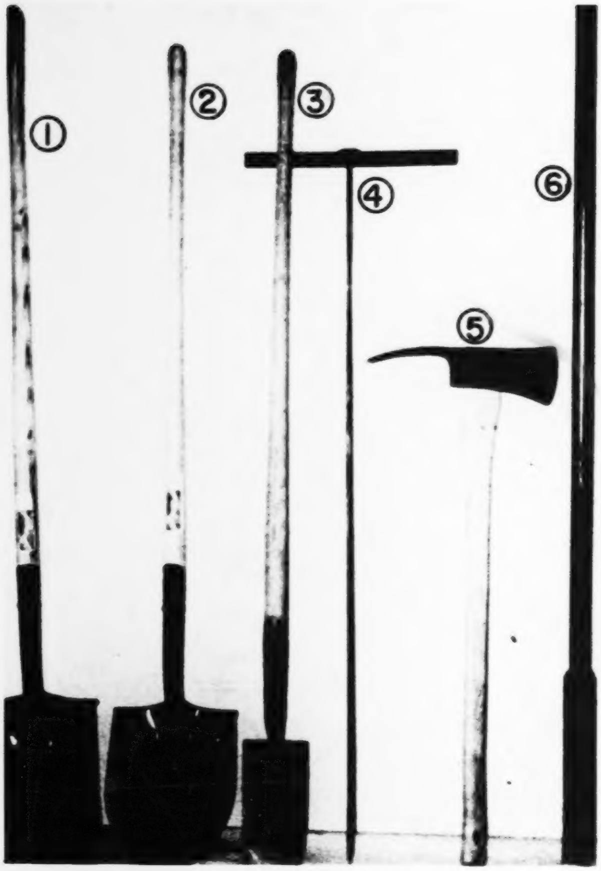


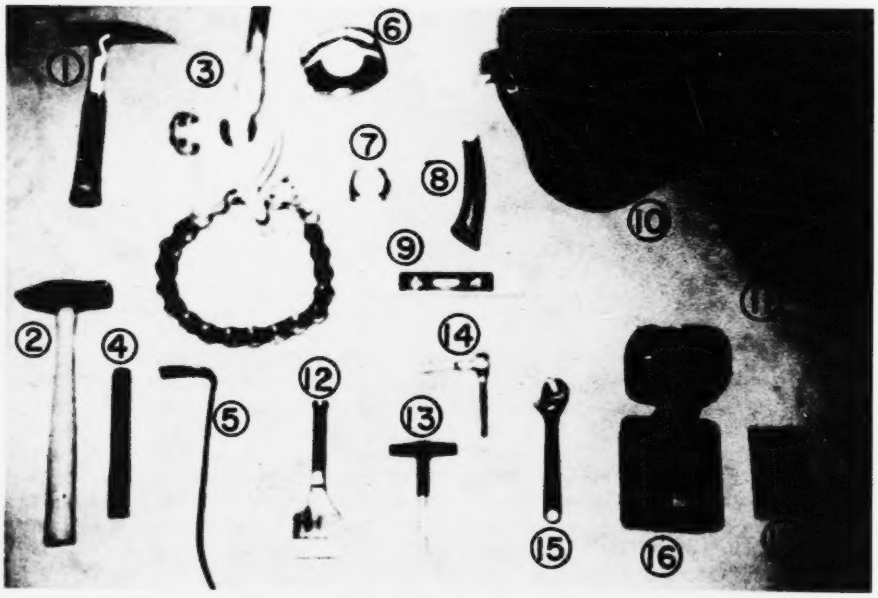
Fig. 7.30 Material for repairs

Tools required by repair crews include round point, square point and narrow cut down shovels (Fig. 7.31). These shovels are used for removing sod and exposing pipe for repair or clean out installation. The narrow shovel is usually made by cutting down the width of a round point shovel that has had the handle broken; however, they may be purchased new. A narrow shovel is used to remove dirt between the pipe and existing ditch line.

Other hand tools may include a miner's pick for cleaning under pipe or for hard dirt near pipes, pipe cutters to cut and remove pipe that is broken or must be removed for the installation of a new fitting, six-foot digging bar, tape measure, rope and a bucket for lowering and removing small hand tools from the excavation, two-pound drill hammer, cold chisel, wonder bar, electrician's chisel, $\frac{3}{8}$-inch drive rachet and $\frac{5}{16}$-inch socket, battery powered lantern and a small hand mirror for looking upstream and downstream once the line is opened to examine for debris left during removal of damaged section. A wide ground cover canvas is helpful to protect lawns. Hydraulic shores, screw jacks and timbers to shore excavations are needed (see Figures 7.12 through 7.19). See Chapter 10, Safety Programs for Collection System Operators, for safety equipment, including a first aid kit.



(a)



(a) 1. Square shovel
2. Round point shovel
3. Narrow shovel
4. Probe
5. Mattock
6. Digging bar

(b) 1. Miner's pick
2. 2 lb. hammer
3. Rachet cutters
4. Cold chisel
5. Wonder bar
6. 50 ft tape
7. 10 ft tape
8. Hatchet
9. Level
10. Bucket
11. Rope
12. Electrician's chisel
13. Torque wrench
14. Rachet and socket
15. Crescent wrench
16. Battery lantern
17. Mirror

Fig. 7.31 Tools used for repairs (b)

7.34 Arrival at Job Site

When traveling to and from the job site, seat belts must be worn. When arriving at the job site, verify that the address and map location are correct. As soon as the truck is parked, traffic cones should be placed on the traffic side of the truck. One cone belongs in front of the truck and the others at the rear of the truck. These cones alert traffic and make drivers aware of the parked repair truck (Fig. 7.32). See Chapter 4, Section 4.11, Traffic Safety, and Chapter 10, Section 10.32, Traffic Control.

TRAFFIC ROUTING
HI! PLEASE TURN BACK AND REVIEW SECTION 4:3 ON PAGE 116

A common practice and a good requirement is to wear a hard hat whenever out of the truck at a job site. Hard hats protect your head from crank-out windows on the sides of homes and buildings and from lines and low clothes line poles.

Notify the property owner that you must enter the property to repair the sewer and install a cleanout on the service line to eliminate the sewer problem. Inspect the area with the property owner. Identify any plants or shrubs that have to be transplanted or replaced.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 419.

7.3A Why should repair assignments be made in writing?

7.3B What items should be reviewed during the preliminary investigation of a work order request?

7.3C What should be inspected before a crew drives to a repair job?

7.3D What should be done upon arrival at the job site?

Fig. 7.32 Placing traffic cones around truck

7.35 Starting Repair (Excavation)

Locate the service line to be repaired. After inspecting the repair area, materials and tools can be brought into the yard. A wide ground cover canvas is placed over lawn grass near the edge of repair area. The canvas helps keep grass from being damaged or destroyed during repair and helps speed backfilling of ditch when job is completed.

Use a square point or a sod shovel to cut an area approximately two feet wide and eight feet long. This 2 × 8-foot section should be cut into smaller sections for ease of handling. Sod sections are placed away from where dirt is going to be stacked. This is to make shoveling dirt into the trench easier. Use the round point shovel to start removing dirt. After about 12 inches of dirt have been removed, a rod or probe is used to locate any possible water or gas lines in the area being excavated that may have been overlooked or forgotten by the utility agencies. In some areas a common practice is to install the water service lines and sewer service lines in the same ditch. Proceed with caution to dig the ditch down to the sewer service line. If a water line is located, caution should be used not to hit or strike the water service line. If utilities are encountered in the excavation of a trench, support the utilities so they won't crack or break. A brace can be placed across the trench and cables extended from the brace to the utilities to provide support. If the sewer service line is deeper than five feet or if hazardous soil conditions are encountered, install adequate shoring (Section 7.2).

Clean the area alongside and under the section of sewer line to be removed to give access to rachet-type chain cutters (Fig. 7.33).

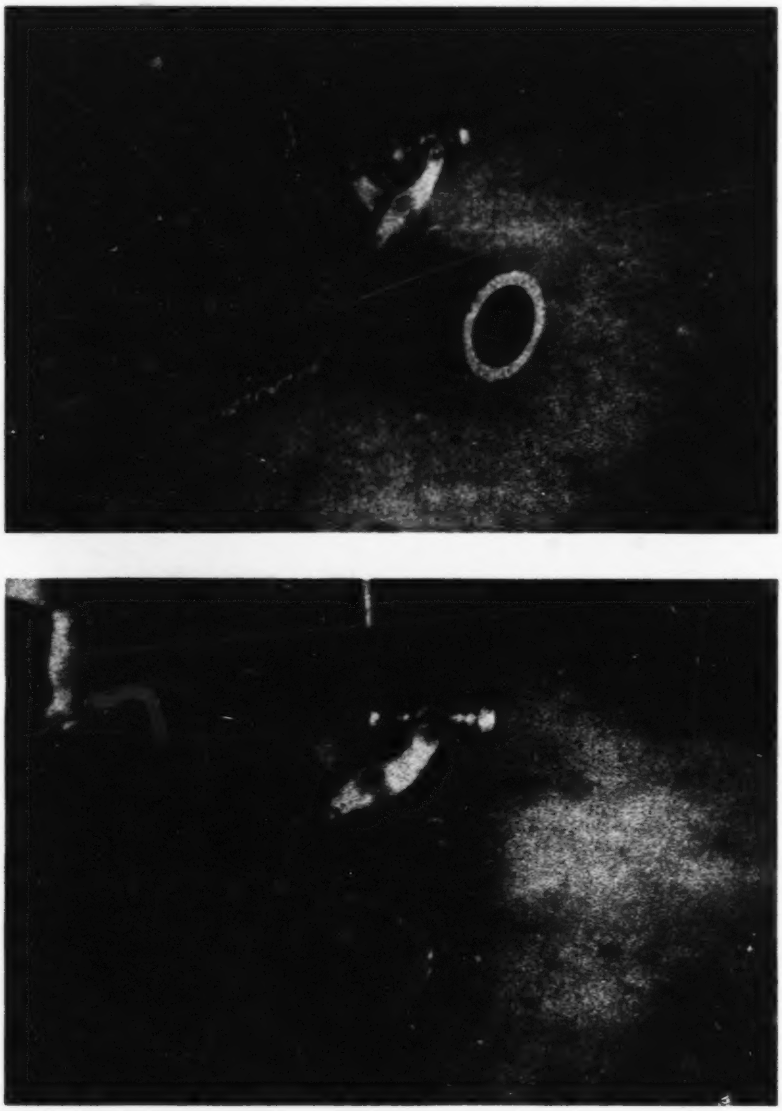


Fig. 7.33 Rachet-type chain cutters

7.36 Cutting Pipe

Rachet cutters are placed on the pipe and end of chain is fed under pipe and attached to jaws of cutters. Be sure that the chain is properly attached. Rachet cutters are marked cut and open. To cut pipe, the side marked *CUT* is aligned with arrow. Apply a downward pressure on handle until pipe is cut. If pipe does not cut during first stroke, lift up on handle until it is at about a 90 degree angle and push downward a second time. Make several cuts (usually three) so pipe section can be removed without damaging remainder of pipe. After the pipe is cut, measure the distance to the next cut, such as for a wye. Install the pipe cutter at the proper location and make the next cut. After all cuts are completed, remove pipe cutter from trench.

Remove section of pipe that has been cut. Be careful not to cut or scratch yourself on the sharp pipe edges.

Inspect service line for any problems using a lantern and mirror. Remove any roots or other obstructions from the line and repair any breaks observed in the line.

7.37 Install Cleanout

If service line is found to be satisfactory or after repair, install a wye. A wye is installed to give access to a portion of the service line leading to the *MAIN LINE*[5] (Fig. 7.34).

Place gravel, sand or crushed rock in bottom of trench for bedding of wye. After wye is in place, install a ⅛ bend or 45° elbow in upper leg of wye if needed. A section of 4-inch clay pipe is then installed into the 45-degree bend and brought up to ground level (grade). A 4-inch plug is inserted on the end of the pipe at ground level. Tighten all couplings or seal joints. Make a quick inspection of ditch for tools before preparing bedding and backfilling trench.

7.38 Bedding, Backfilling and Compaction

Proper bedding is very important. Be sure bedding is of suitable soil or material to provide a firm base. Tamp the bedding so it won't settle after the job is completed. A smooth bedding surface is essential to prevent the cleanout or pipes from shifting.

Start to backfill the ditch. A square point shovel is often used for backfilling. A water hose is required for jetting. The hose is placed near the bottom of the ditch. As dirt is being backfilled into ditch, the hose is pulled up to allow all backfilled soil to be soaked. This process provides compaction of soil in the ditch and prevents extreme settling from occurring at a later date.

Care must be taken to prevent large chunks of dirt or rocks from striking the sewer service line. Pipe breakage can occur or a coupling can be knocked off, causing a leak to develop.

After all dirt has been replaced into the ditch and the sod and bushes put back in place, a visual inspection of the repair area should be made to be sure the work area has been returned as close to original conditions as possible. Be sure all tools have been accounted for, cleaned and loaded on truck. Notify the resident of the home when the job is completed.

7.39 Complete Service Line Location Card

Measure the distances of the cleanout from both property lines. These measurements and a sketch of the area are for future reference to help locate the cleanout (Fig. 7.35). *RECORD* observations of conditions and problems encountered during any repairs and installation of cleanout.

Before entering truck, carefully walk around truck looking for children, toys and other items and then pick up traffic cones. Also look inside the trucks and equipment for children.

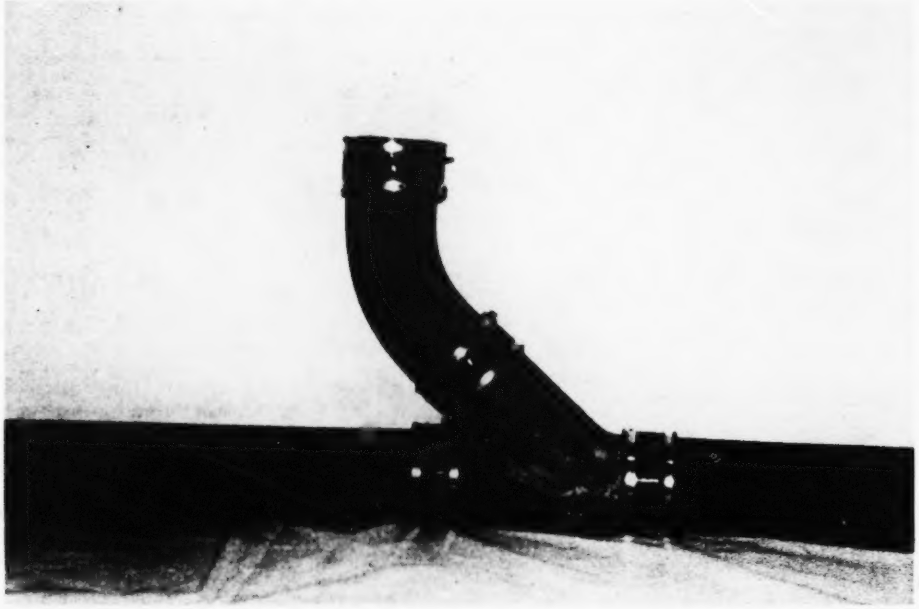
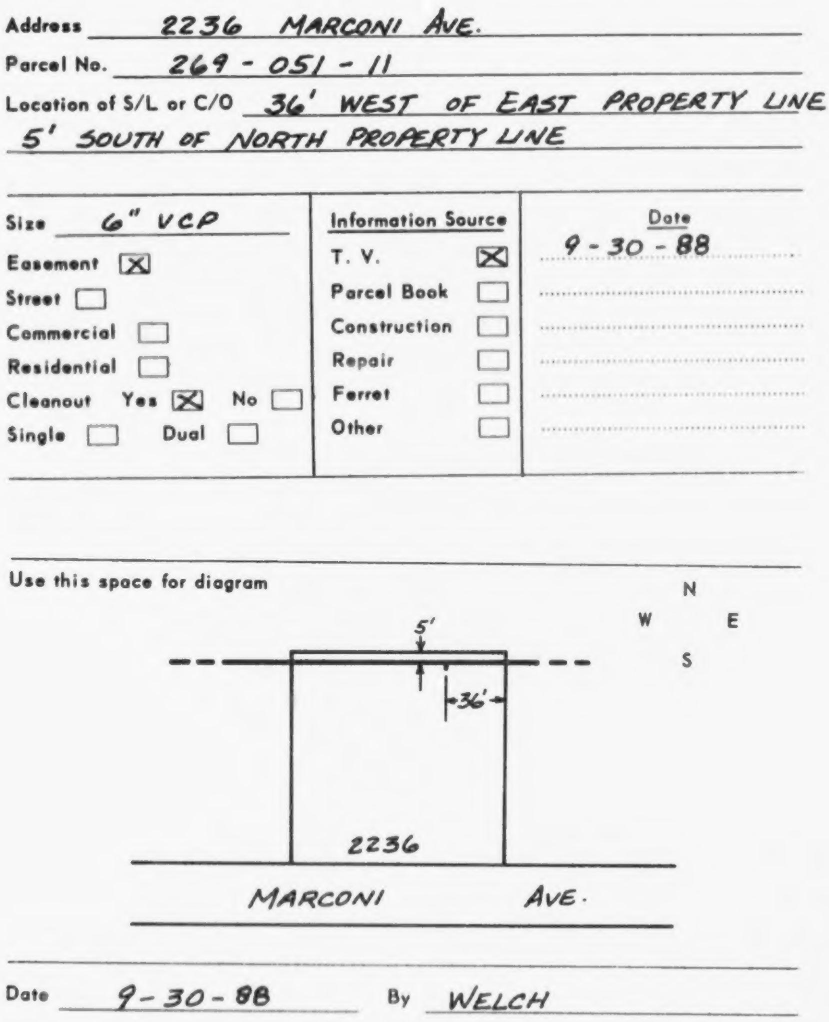


Fig. 7.34 Wye and cleanout

---

[5] *Main line. Branch or lateral sewers that collect wastewater from building sewers and service lines.*



Address 2236 MARCONI AVE.

Parcel No. 269 - 051 - 11

Location of S/L or C/O 36' WEST OF EAST PROPERTY LINE
5' SOUTH OF NORTH PROPERTY LINE

Size 6" VCP	**Information Source**	Date
Easement ☒	T. V. ☒	9 - 30 - 88
Street ☐	Parcel Book ☐	
Commercial ☐	Construction ☐	
Residential ☐	Repair ☐	
Cleanout Yes ☒ No ☐	Ferret ☐	
Single ☐ Dual ☐	Other ☐	

Use this space for diagram

N
W
E
S
5'
36'
2236
MARCONI
AVE.

Date 9-30-88 By WELCH

Fig. 7.35 Service line location cards

Upon returning to maintenance yard, discuss with your foreman any future problems that you think might develop. Potential problems include plants destroyed, trees hit, fence posts weakened, or a need for more dirt after settling. This information gives the foreman a chance to discuss these problems with the property owner and usually can avert some bad public relations at a later time.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 419.

7.3E When excavating to repair a sewer line, why should the soil removed from the excavation be placed on a canvas?

7.3F What cautions should be exercised when excavating to repair a sewer line?

7.3G What is done after a section of pipe is cut and before a cleanout is installed?

7.3H What kind of bedding material is used for the wye of a cleanout?

7.3I What should be done before a trench is backfilled?

7.3J What is the purpose of the service line location card?

7.3K What should the crew leader do upon returning to the yard?

7.4 MAIN LINE REPAIR

Main line repairs are required when a sewer line repeatedly shows partial or complete stoppage of flow. Partial stoppages may require only cleaning. Broken and collapsed pipes and offset joints are examples of sewers needing repairs. To describe the procedures for repairing a main line, let's replace a section of 8-inch sewer in the street.

7.41 Preliminary Field Investigation

Before starting repair of a main line, the foreman makes a preliminary field investigation to identify potential problems, obtains necessary permits and plans the repair job. A work order prepared by the TV inspection crew indicates that a section of 8-inch sewer needs replacement. Paint is used to mark the repair area on the street surface. All utility companies are contacted and requested to identify the location of their utilities in the area of the repair site. Representatives of the utility companies involved (water, natural gas, fuel pipe lines, electrical power and telephone) meet with the foreman at the site and mark the location and depth of their system. Contact local traffic control agency if permits are needed to reroute traffic or any other problems handling traffic are anticipated. Review the "as built" drawings for any helpful information such as the type of pipe and bedding. Examine any records that could reveal the elevation of groundwater. Also determine if pumping of wastewater or groundwater will be required until the repair is made.

7.42 Crew and Assignment

This main line repair job requires at least a three-operator crew. The crew chief is a collection system repairman (Maintenance Man II) and a qualified backhoe operator (Construction Equipment Operator). The crew chief is helped by two assistant collection system repairmen (Maintenance Man I). In some states the driver of a vehicle that transports equipment to a job site may have to obtain a special driver's license.

A collection system supervisor (foreman) reviews the work order and prepares a time sheet. Also the foreman prepares a sketch of the job site showing the location of all utilities and other important information. This preliminary information, the proper procedures and safety precautions, and the necessary equipment, tools and materials are discussed by the foreman with the crew chief.

7.43 Materials, Equipment and Tools

Materials required for this particular job include sections of 8-inch vitrified clay pipe, 8-inch band couplings and sufficient crushed rock to prepare a bed for the new section of 8-inch pipe to be replaced.

Equipment required for this job includes a backhoe, dump truck, tilt bed trailer, 1½ ton flatbed truck equipped with an air compressor to operate a pavement breaker and a pneumatic tamper, and a water truck with a 1500-gallon capacity tank.

The dump truck pulls the trailer loaded with backhoe. The 1½ ton flatbed truck carries all pipe repair materials, air and hand tools and safety equipment (shoring, personal and traffic control). The water truck has a portable 2-inch pump mounted on the tank and carries all the hoses and pipe needed for jetting purposes during backfill. A 24-foot aluminum extension ladder and extra shoring jacks and sheeting for bigger and deeper jobs also are carried by the water truck. All portable equipment (such as equipment on trailers) pulled to a job site must use a pintle hook and have a safety cable placed around the pintle hook and portable equipment.

Before the crew leaves the yard, they inspect all equipment (including safety) and determine that all the necessary equipment, tools and materials needed to do the job are loaded on the trucks. Hard hats should be worn by the crew at all times. See Chapter 11, Safety/Survival Programs for Collection System Operators, for safety equipment, including first aid kit.

7.44 Arrival at Job Site

When the crew arrives at job site, they locate the marked repair area and park trucks in safe and convenient locations. The flatbed truck should be parked close to the repair area so it can be reached with air hoses and pavement breaker. Prepare traffic control using high flags and traffic cones (see Chapter 4, Section 4.3, Traffic Safety and Chapter 11, Section 11.2, 10. Traffic Mishaps) to protect equipment, work area and operators. Contact the homeowner and owners of parked vehicles that are in the work site area or in driveways that will be blocked during repair of the main line. Explain to these people that a major repair on the sewer line must be done now and request their cooperation. Assist them, if necessary, to minimize inconvenience while doing the job. If parked vehicles are a potential problem, the job site can be barricaded and marked the night before or very early in the morning.

TRAFFIC ROUTING
HI!
PLEASE
TURN BACK
AND REVIEW
SECTION 4:3
ON PAGE
116

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 420.

7.4A What should a foreman do before a crew is assigned a main line repair job?

7.4B What information does the foreman need from other utility agencies at the job site?

7.4C What items are discussed by the foreman and crew chief before the crew starts the job?

7.4D What should the crew do before leaving the yard for the job site?

7.4E What should the crew do when arriving on the job site?

7.45 Cutting Pavement

After observing traffic flow for proper control and safety, the area of the pavement to be cut is marked off with a chalk line. The cut in the pavement should be 30 inches wide and 10 feet long for this job. Before marking and cutting, verify the repair locations by measuring the distance from the designated manhole. Also measure the distance from manhole to manhole and other important distances to verify the accuracy of the sketch.

Start the air compressor and allow it to warm up. An assistant collection system repairman (Maintenance Man I) puts on safety glasses, ear plugs, and required safety shoes. A cutting blade or other suitable tool, depending on type of pavement, is locked into the pavement breaker. The air hose is connected and the safety chains are locked in place. The safety chain is required to prevent the air hose from whipping around if the hose connection comes uncoupled from the breaker. Some hose connections are equipped with a double-spring lock and do not require a safety chain.

Cut the pavement along the chalk lines. While the pavement is being cut, the backhoe is unloaded from the trailer and lubricated. The trailer is unhooked from the dump truck and parked. Crushed rock is dumped near the repair area for later use.

Open the upstream and downstream manholes. Observe and record the amount of flow and the depth to the top of pipe. This depth indicates to the backhoe operator how deep to excavate. Also this observation can reveal if the line is plugged by causing flow to back up into the manhole.

After the black top is cut, the pavement breaker and air hose are put away and the flatbed truck is moved to make room for the dump truck and backhoe. The hoe operator examines the work order for the location of utilities and confirms their locations in the marked area.

7.46 Excavation

Start digging with the backhoe. Load directly into dump truck the black top or road surface, subbase rock, and the soil down to about two feet below the road surface. Watch for changes in soil texture or other signs that could indicate the presence of cross trenches or other underground utilities.

At this depth, determine if spoil (excavated materials) are suitable for backfill. Usually the original trench backfill material will make suitable backfill material again.

Dump truck travels to gravel plant to dispose of excavated pavement and subbase and returns with approximately three yards of 1½ inch road rock. Continue digging with backhoe. Keep the spoil pile at least four feet from the edge of the trench if the trench is over five feet deep. If shallower, spoil must be at least two feet from edge of trench; however, a distance of four feet is recommended. An assistant repairman (Maintenance Man I) uses a square point shovel to keep the working area clean. Everyone must be alert. Watch the backhoe and the trench for signs of utilities and anything unusual. Continue excavating until approximately 1½ feet above the sewer main line which is to be repaired. Use an extension probe to determine the exact distance to the main and the amount of material remaining over the top of the main. The backhoe operator must be careful to avoid damaging the line. If shoring is necessary, refer to Section 7.2, Shoring.

The backhoe continues to dig down to within six inches of the main, depending on the operator. Continue to determine the location of the main line with the probe. Do not break the main line.

If water is encountered, a sump will have to be dug. Use a trash pump to remove the water and discharge it into a manhole or catch basin. By now the dump truck has returned with the gravel and is parked out of the way.

7.47 Pipe Repair

After the shoring is installed and the trench is determined safe, place a ladder into the trench. Leave the ladder in the trench as long as an operator is in the trench.

A round point shovel is lowered on a rope to the operator in the trench to uncover the main line and locate the problem area. A narrow shovel is used to dig alongside of the pipe and to dig down below the main line when necessary.

A miner's pick and wonder bar are lowered down in a bucket to the operator in the trench. These tools are used to dig under the main line about a foot and a half each way from the broken bell section of the pipe which is to be replaced.

Remove all loose dirt from under the pipe before cutting the pipe for repairs. When the main line is cut, the flow drops into the trench, fills the hole and flows out the downstream pipe. If loose dirt is not removed, this water will mix with the loose dirt and form a sloppy mess unsuitable for bedding material.

Have a sump pump and hose standing by in case water in excavation must be pumped out. Pump to the downstream pipe or to a downstream manhole. If possible, it may be necessary to plug off flows at the upstream manhole while the pipe is being repaired. Be careful not to flood any homes, businesses, or streets whenever plugs are used. If necessary, pump wastewater from upstream manhole to a downstream manhole.

To prepare for cutting the pipe, the repairman in the trench must be wearing safety glasses, steel toe rubber knee boots and gloves. Lower the pipe cutters into the trench to the repairman. Cut the pipe approximately one foot on each side of the break in the main line. Wrap cutters around the main and cut the pipe two or three times at both locations where the pipe is to be cut. This many cuts are necessary so the good pipe won't chip or crack when the damaged section of pipe is broken out. Use the miner's pick to break out the bad pipe. Remove the pipe and debris from the trench using a bucket and rope.

Lower a mirror and flashlight into the trench. Inspect the main line for cracks, roots, and bad taps and joints in both directions from the cut.

Measure the distance between the cut pipe ends — for example, 25 inches. Inform the operators topside of the length needed. Cut a 24½ inch long piece of pipe off a section of 8-inch diameter pipe. This leaves a ¼-inch gap at each end of the repair section to allow the centering stop of the band couplings to fill these gaps. The pipe used for repair does not have to be made of the same material as the original pipe. PVC (polyvinylchloride) and plastic truss sewer pipes are used to repair vitrified clay pipes and are connected together using band couplings and bushings.

Lower the bedding material in buckets and place it in the void under the pipe. Leave enough room at the cut ends to slide couplings around the existing main line.

Center two 8-inch band couplings on the ends of the new pipe section and mark the location with a pencil or anything handy for a centering reference. Lubricate and slide the couplings completely over the new pipe section so the ends are even or flush.

Lower the short piece of pipe and couplings into place between the main line ends. Slide the couplings over the existing main to the reference marks on the pipe as previously discussed. The coupling's center stop should drop into the ¼-inch gap. If the band coupling does not seat, rotate the pipe section.

Tighten the stainless steel bands with a special torque speed wrench designed for the band couplings. If the wrong wrench is used, the pipe can be damaged.

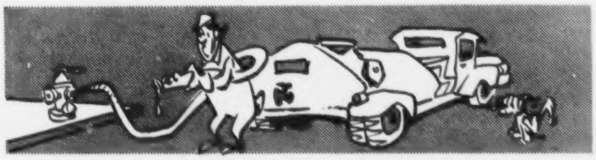
Collection system operators are continuously working with manufacturers to develop more cost effective and permanent means of repairing sewers. Broken, crushed or badly cracked main lines greater than 12 inches in diameter may be repaired by the insertion of a special PVC pipe. This pipe must be made for a specific segment of existing pipe needing repair. The new PVC pipe consists of four segments (long quarter sections) which are pushed or pulled to the damaged area. The segments are expanded into place with internal jacks. The four joints of the four segments will pop into place and the new pipe becomes self-supporting.

A method of repairing leaking joints is to place a neoprene seal over the entire inside joint of the pipe. The seal is placed by hand and must be wide enough to span the existing joint. An expanding stainless steel band is placed inside the neoprene seal and enlarged. The pressure provided by the expanded band holds the seal in place and prevents any leaks.

7.48 Bedding, Backfilling and Compaction

(See Chapter 3, Section 3.72, Sewer Pipe Bedding and Initial Backfill, page 82.)

Move bedding material into the trench and place around the main line with a shovel. Be sure alignment of the pipe is proper for a smooth, even flow. The bedding material should be compacted until it completely covers the pipe by 6 to 12 inches.



All the tools no longer needed for the job are cleaned and put away. The water truck is filled with a load of water from the nearest fire hydrant to jet the trench. Use a backhoe to ease the excavated material back into the trench.

Park the water truck close to the repair area, and a section of 1½-inch pipe is connected to the hose from the pump. Turn on the water. Start the pump. Push the pipe into the loose soil while the water is running all the way to the bottom of the trench. As the water spreads out and works its way upward, observe the top of backfill soil settling. When water is seen breaking to the surface, the pipe is pulled out and moved down the ditch 3 or 4 feet and the procedure is repeated until the entire ditch is jetted. The soil should drop to about a foot below the pavement.

The dump truck is backed to the trench and dumps the road rock to fill the ditch to a level about one foot above the pavement.

Wheel roll the gravel with the backhoe. After rolling, the gravel should drop to a level about even with the pavement.

Start the air compressor to supply air for the pneumatic tamper to better compact the road rock to 1 or 1½ inches below the pavement. Practice good housekeeping and clean up the area using a square point shovel and street broom.

Mechanical compaction methods (tampers) are often used instead of water compaction in roads and streets. The soil used for backfill should be fairly dry before it is paved over or soft spots could develop under the pavement.

7.49 Safety

Two barricades with flashers are placed over the repaired area and left there until the paving crew can complete the patch job. Some agencies will fill the hole with a temporary black top patch and the final restoration is done at a later date.

Complete the clean-up by washing down the street work area.

Connect the trailer to the dump truck and load and secure the backhoe. Time required and materials used are recorded (Fig 7.36). The crew proceeds to the next job after all tools are cleaned and placed in their respective vehicles and the equipment is secured and ready to go.

LABOR

Foreman	______	Hrs	$______
Repairman	______	Hrs	$______
Asst Repairman	______	Hrs	$______
MM	______	Hrs	$______

EQUIPMENT

Dump	______	Hrs	$______
Trailer	______	Hrs	$______
Backhoe	______	Hrs	$______
1 1/2 Ton	______	Hrs	$______
Compressor	______	Hrs	$______
1 Ton	______	Hrs	$______

MATERIALS

________	$______	________	$______
________	$______	________	$______
________	$______	________	$______
________	$______	________	$______
________	$______	________	$______
________	$______	________	$______
________	$______	________	$______
________	$______	________	$______
________	$______	________	$______

TOTAL COST $ __________

Fig. 7.36 Labor, equipment and materials card

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 420.

7.4F Before cutting the street, what should the crew verify?

7.4G How can the crew tell if unidentified utilities might be in the work area?

7.4H Is spoil from an excavation suitable for backfill?

7.4I How far should the spoil pile be kept from the trench?

7.4J How is the elevation of the line being repaired determined?

7.4K How close does the backhoe dig to the main line?

7.4L How are equipment and material lowered into the trench?

7.4M Why should all loose dirt be removed from under the main line?

7.4N How is the backfill compacted?

7.4O How is the job site protected until the patch crew arrives?

7.5 SPANNING EXCAVATIONS

Ductile iron pipe (DIP) and polyvinylchloride (PVC C-900) water pipe are installed when sewer lines cross the excavations or trenches of other utilities. Dig on each side of the excavation being crossed so that there is at least 18 inches of good, solid undisturbed soil for the spliced in DIP or PVC C-900 pipe to rest on with proper bedding. This procedure prevents future problems if the backfill in the excavation being spanned settles. When a pipe with joints settles, leaks can develop and eventually cause more settlement and possibly a wash out.

Use crushed rock bedding material on all repairs. Place the crushed rock under the existing pipe ends and under the spliced in section. Bring the crushed rock up to the springline (center of the pipeline) of the pipe with attention to support of the haunch areas (lower quarter of pipe on each side). Complete the bedding by placing crushed rock all around the pipe.

Band and repair couplings are commonly manufactured for pipes up to fifteen inches in diameter. Couplings and sleeves for larger diameter pipe are available as special orders from some manufacturers.

Field joints may be made for pipe when band couplings are not available or for large diameter pipe. A field joint is made by using a cloth inserted packing (CIP) which is manufactured in rolls. CIP is a thin material which is strong and easy to cut out and handle. A neoprene packing with synthetic cloth (CIP) is better than natural rubber and cotton which was used before the development of CIP.

Cut the CIP to the length and width needed. The length should overlap each end by at least six inches. Wrap the CIP around the pipe ends and coat the overlapping packing ends with rubber adhesive.

Place one or more stainless steel straps on each side of the joint with a hand banding tool. The CIP becomes the inside form so concrete can be placed around the joint. Concrete reinforcing bars, concrete netting or stucco netting may be used for reinforcement to provide additional supporting strength. Make a wooden outside form to contain the concrete. Pour the concrete and vibrate or work the concrete under and around the pipe.

After the concrete has set, finish backfilling the trench and completing the job. Once the CIP is in place and the flow is not too great, the sewer line may be placed in service.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 420.

7.5A How can future problems be avoided which are caused by the settling of backfill in an excavation being spanned?

7.5B What type of bedding should be used for sewers spanning excavations?

7.5C What type of pipe material should be used when sewer lines cross the excavations or trenches of other utilities?

END OF LESSON 2 OF 3 LESSONS
ON
UNDERGROUND REPAIR

DISCUSSION AND REVIEW QUESTIONS

Chapter 7. UNDERGROUND REPAIR

(Lesson 2 of 3 Lessons)

Write the answers to these questions in your notebook before continuing.

7. Why should repair assignments be made using work order forms?
8. What must be done before repair work on a sewer is started?
9. When should hard hats be worn and why?
10. How would you install a cleanout easement?
11. How would you replace a tap full of roots in a main line located in a street?
12. During excavation, how would you attempt to look for the location of unknown underground utilities?

7.6 SEALING GROUT

Several methods or techniques are available today for internal grouting or sealing of sewer pipes. This section describes one technique — grout sealing. Other techniques are available and provide similar results. Grout sealing is used to illustrate the reasons for internal grouting or sealing and the procedures.

Grout sealing is one method of internal chemical sealing. This particular method is a process that is designed to re-form the gasket of the leaking pipe, and seal at the site of the leak, rather than stabilize soil as in other sealing methods.

Technology is continually developing newer and more effective sealing compounds. These compounds may seal the pipe joint or crack, or seal a leak and stabilize the soil, or possibly even chemically control roots, stabilize soil and seal a leak. Before selecting a sealing compound, try to identify the problem or problems you wish to correct, determine what compounds and procedures are available, discuss their effectiveness with other operators who have used the sealant and equipment, and select what you think will do the best job for your agency. For ideas on how to select a sealing compound and procedures, review Chapter 5, Section 5.44, Purchase of Closed Circuit TV Equipment, and Chapter 6, Section 6.22, How to Select Chemicals.

7.61 Reasons for Grouting or Sealing Sewers

Of the various sewer rehabilitation techniques used today, internal sealing is one of the most widely used methods. Internal sealing is effective when the sewer line to be repaired is in an area that is unsuitable for excavation, and is either infiltrating or exfiltrating through leaking joints, cracks, or small holes. Where the structural integrity of the sewer is gone due to collapsed sections or severe cracks or holes, sealing is not ideally suited to solving the problem. Under these conditions, structural repairs are necessary to insure structural stability before sealing the remaining parts of the sewer.

Frequently agencies attempt to stop infiltration in order to reduce flows to wastewater treatment plants, especially during heavy rain storms. When stopping leaks into a sewer through joints that are infiltrating, you must realize that the water table around the sewer can increase in elevation. Water that once infiltrated into the sewer will now be stored in the trench bedding material. This water will build up a head on the sewer and also move up the sewer looking for more poor joints. For this reason, all joints must be tested and sealed if necessary. Also, if wastewater has been escaping from a sewer by exfiltrating through bad joints, the sealing of these joints could increase the flow to the wastewater treatment plant. These potential impacts on flows and joints must be considered when evaluating the results of a sealing program to prevent infiltration and exfiltration.

The sealing process consists of using a closed circuit television system and a packing device. The TV camera monitors the "packer" as it is placed on leaking joints in the pipeline. When the packer is positioned correctly, a pumping system is activated to inject the sealing chemicals or grout into the leak. The use of internal chemical sealing does not require excavation, nor does it require the interruption or by-passing of wastewater except in extreme conditions. Sealing compounds have been developed which are so effective that well points do not have to be sunk to dewater the area and prevent washout of sealing compound.

The uses of sealing include rehabilitation of existing sewers to reduce infiltration/exfiltration and manhole sealing. Sealing processes also are used on new construction of sewer lines where the contractor is unable to pass the line acceptance test, be it either air testing, water testing or weir measurements. Sealing in many cases avoids further delays and costly excavation.

7.62 Equipment

Sealing equipment is generally used by two groups of individuals — the agency, whether it be county, municipality, or utility district, and the contractor who specializes in TV inspection and sealing. Of the two groups, the contractor is the one who does a majority of the sealing projects. In either case it is a good idea to be familiar with the sealing process since most communities at one time or another will employ sealing whether through a contractor or with their own equipment.

The following list indicates the basic system requirements (Fig. 7.37) of a grout sealing system and briefly describes the use of each component.

AIR COMPRESSOR — The system is air activated. Compressed air is used to operate the pumps and inflate the sleeve packer.

CHEMICAL PUMP — The sealing chemical is pumped through hoses down into the sewer to the sleeve packer.

WATER PUMP — Water (catalyst for the chemical) is pumped through hoses down into the sewer to the sleeve packer.

CONTROL PANEL — The activation of the two pumps and the inflation and deflation of the packer are controlled from the panel. The entire sealing process is monitored and operated from this panel.

SLEEVE PACKER — The actual component that does the sealing down in the sewer. This component is inflated pneumatically to isolate the leak and forces the sealing chemical into the leaking area.

When using the grout sealing process it is unnecessary to mix the sealing chemical. It is pumped directly out of its shipping container and the water is pumped out of its container. As long as water reaches the grout sealing chemical, the reaction will occur.

While this list covers the basics of the system, there are other items involved such as interconnect hoses, assorted valves and fittings, a hose reel, and a *PENTA HOSE*[6] to carry the air and chemicals to the packer.

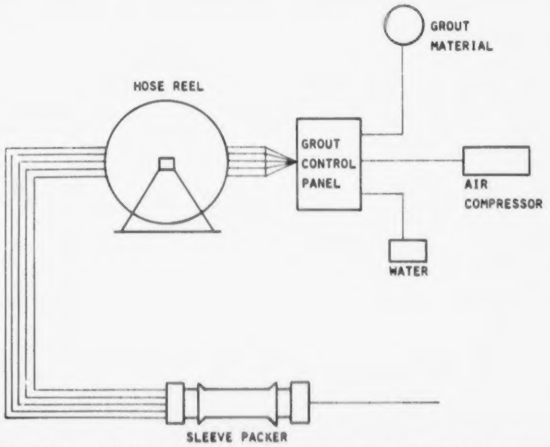


Fig. 7.37 Major components of a grout sealing system

---

[6] *Penta hose. A hose with five chambers or tubes.*

7.63 Sealing Chemicals

The sealing material may be some type of *HYDROPHILIC*[7] POLYMER[8] or other type of sealing chemical grout which is applied to a sewer pipe joint or defect by use of the sleeve packer. The solids content plays an integral part in choosing a sealant chemical, since the sealing chemicals used may shrink to the volume of the solid material if moisture conditions are not maintained.

When the sealing material is mixed with an equal quantity of water (a special accelerator is added for winter conditions), the material expands 10 to 12 times its original volume and cures to a tough, flexible, elastic condition. As a note, the chemical will absorb the water it needs to react, which is an equal volume, and dispel the remaining water in its immediate surroundings. As is the case in actual sealing operations, there is always excess water present when sealing leaks, but this excess water is usually not a dilution factor.

Grout sealing chemicals should have the following properties:

1. Resistance to most organic solvents, mild acids and alkali,
2. Returns to shape after repeated deformations,
3. Essentially non-toxic in cured form,
4. Does not become rigid or brittle when exposed to freeze-thaw or dry or low moisture conditions, and
5. Noncorrosive and does not contain neurotoxic ingredients in either cured or uncured form.

Figure 7.38 shows the approximate chemical quantities in fluid ounces of grout per pipe joint used to rehabilitate different types of pipes and different sized pipes. These quantities have been established by actual field experience, but may vary slightly depending on the condition of each specific joint. Factors which may affect the chemical quantities include original gasketing materials remaining in joint, open or offset condition of joint, or severity of infiltration or exfiltration.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 420.

7.6A Under what conditions can grouting or sealing be considered an effective method to repair or rehabilitate a sewer?

7.6B What are the basic pieces of sealing equipment?

7.6C What are the desirable properties of chemical grout sealants?

7.64 Sealing Process

This next section describes the chemical grout sealing process on a typical 8-inch leaking joint. While this does not cover all aspects of sealing sewers, it does provide an adequate example of stopping the most commonly encountered leaks. Special leaks, extreme conditions, badly cracked pipes and other situations are best done with the consultation of the equipment manufacturer.

7.641 Set Up

The camera and sleeve packer are connected together with the camera turned around to look at the packer (Fig. 7.39). The air and chemical hoses are then connected to the sleeve packer and each mode is tested to insure operation before lowered into the line.

7.642 In Line

The camera and sleeve packer are then lowered into the manhole, and guided into the sewer line as the cable winch at the opposite manhole slowly pulls the units through the line (Fig. 7.40). As a note it is better to have the camera on the downstream side of the packer because the water build up cuts valuable time from the operation and obscures much of the visual inspection of the process. Also the camera can reveal any grout getting around the packer. Manhole rollers and jacks are placed in the manhole to prevent gouging and scraping the hoses and cables as they move through the manhole.

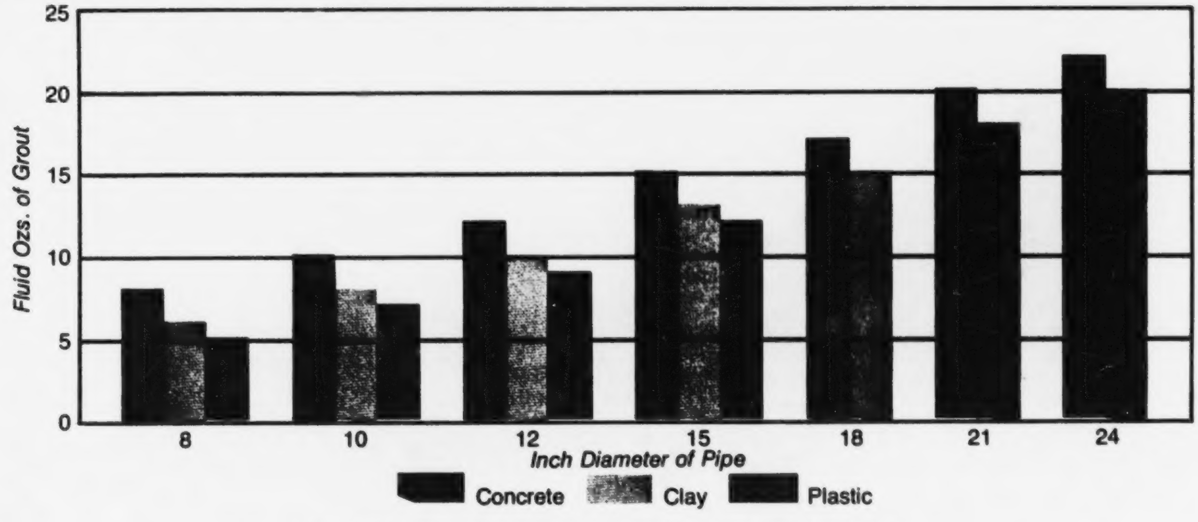


Fig. 7.38 Chemical quantities used for different pipe joints

---

[7] *Hydrophilic. Water loving.*

[8] *Polymer. A high-molecular-weight substance that is formed by either a natural or synthetic process. Natural polymers may be of biological origin or derived from starch products, cellulose derivatives, and alignates. Synthetic polymers consist of simple substances that have been made into complex, high-molecular weight substances. Often called a "polyelectrolyte."*

Fig. 7.39 TV camera and packer

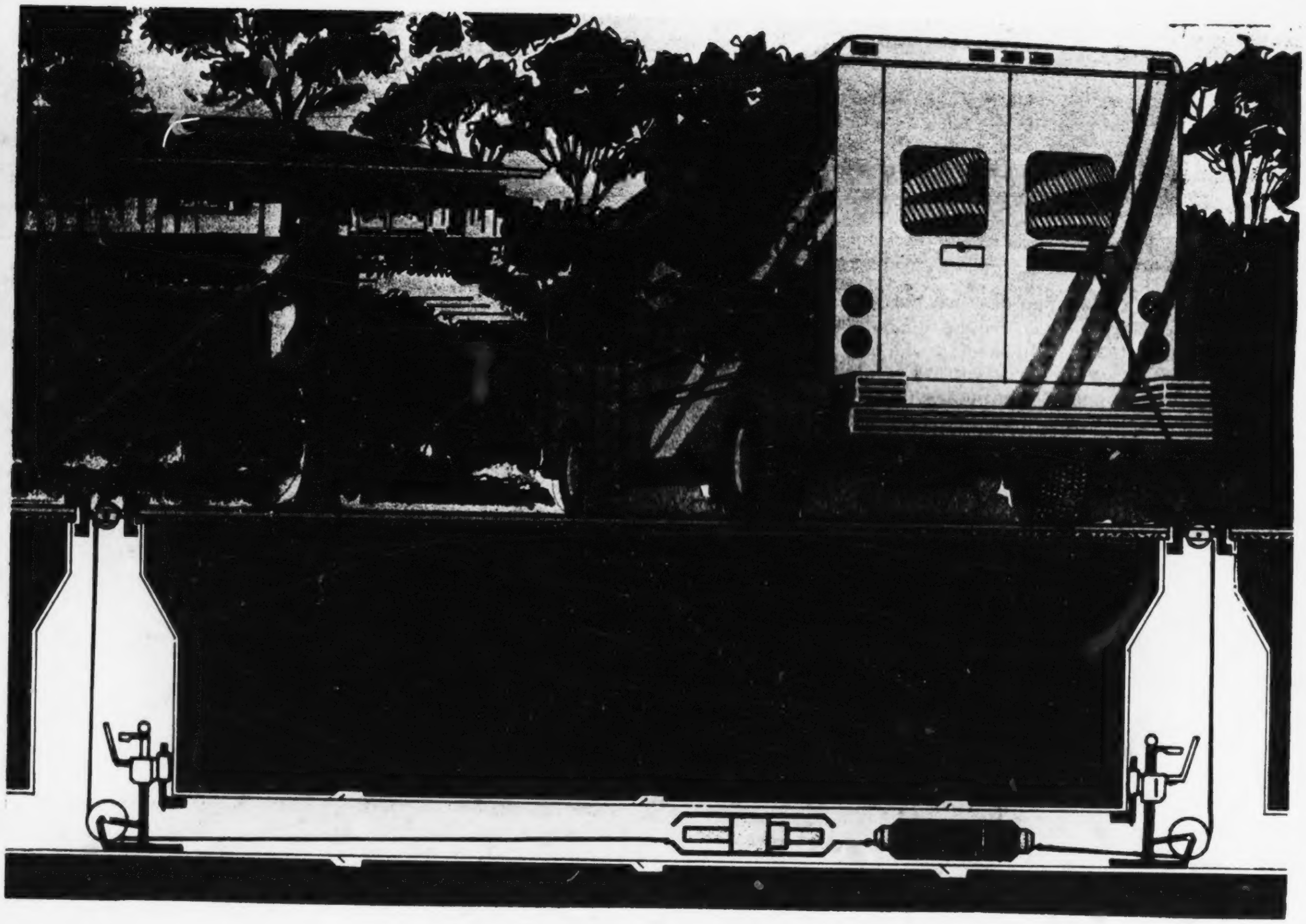


Fig. 7.40 In line operation

The camera and packer are then winched to the nearest leak to be tested or sealed.

7.643 Testing and Sealing

Once the sleeve packer is centered on the joint, the test may be run (Fig. 7.41-1). It is necessary to test only those joints where visible leaking is not evident. All leaking must be sealed. The first step of the test is to inflate the end elements. Water is then pumped into the isolated area formed by the inflation of the end elements (Fig. 7.41-2), and the pressure in the center area on the packer is monitored for an increase to ascertain the integrity and tightness of the joint. The pressure in the center area of the packer may be set anywhere from 0 to 15 psi depending on the depth of the line and water table condition.

Once a leak has been detected, either through visual observation or through detection from testing, the equipment is then placed into the grout mode (Fig. 7.41-2). Three (3) timers are set: one is the length of time that the chemical is injected, the second determines the reaction time from liquid to "foam," and the third timer controls the cure time. After these timers are set, the grout switch is pushed and the machine automatically pumps the chemical, allows it to react with water, and inflates the center area on the packer to squeeze the foaming chemical into the leak (Fig. 7.41-4). A post-seal test may also be run to insure the joint has been effectively sealed to desired pressure.

The entire process will average out to about 5 minutes per joint when each joint is tested — sealed — retested. Winter time operations will take longer due to the extra freeze prevention precautions that are taken and due to the fact that the chemical will react more slowly as it gets colder.

7.644 Clean up

Once the manhole section of sewer has been sealed and tested to the engineers specifications, the camera and packer are removed from the line and clean up of the unit takes place. The hoses and cables should be wiped free of wastewater as should the camera and sleeve packer. It is unnecessary to disconnect the sleeve packer from the hoses since the packer is a self-sealing unit and there is no danger of the chemical sealing up in the packer if the unit is going to be used within three or four days. If the unit is to be idle for more than six days, the packer should be disconnected from its hoses and cleaned thoroughly.

It is not necessary to empty the hoses of sealing chemical unless the unit is to be idle for a long period of time, such as a winter time lay-over.

7.65 Specialized Applications

7.651 Roots

The use of root inhibiting chemicals with the sealing material is not recommended unless the roots are killed and removed prior to the sealing operation. The reason for this is that if you seal a joint with roots in the joint and then pack a chemcial with a root inhibiting or killing agent into this area, it will kill the roots. The roots will then die and leave a hole when they decay and infiltration or exfiltration problems are back again. Roots should be killed, removed, and then the root inhibiting chemical added to the sealing chemical for use in the sealing operation.

7.652 Large Diameter Pipe Sealing

Special equipment is placed in the line which is designed to be lowered through a standard manhole and moved through the pipe to each joint to be sealed. The special sealing equipment does not damage, break or cause settlement, assuming the line is structurally sound.

The sealing equipment consists of two separate pumping systems capable of supplying a flow of sealing materials to form a new gasket or a seal on the infiltration or exfiltration point. The sealing material passes from the pumping system through hoses to the sealing device. This device (referred to as a packer) is a cylindrical case of a size less than the pipe size and consists of a steel ring, two inflatable end elements and one packing element.

Special care is used to prevent damage to the pipe from excessive amounts of sealing pressure. The packer is manually positioned over the area of the infiltration or exfiltration and the two inflatable elements are expanded using precisely controlled pressures (Fig. 7.42). These elements seal against the inside periphery of the pipe to form a void area at the point of infiltration or exfiltration which is now completely isolated from the remainder of the pipe lines.

Into this isolated area, the sealing chemical is pumped through the hose system (Fig. 7.43). The amount of sealing material will be determined by the size of the pipe and the condition of the joint. After the sealing material has been pumped into the isolated area, between the two elements, the packing element is then inflated, thus forcing the sealing material into the defective joint (Fig. 7.44).

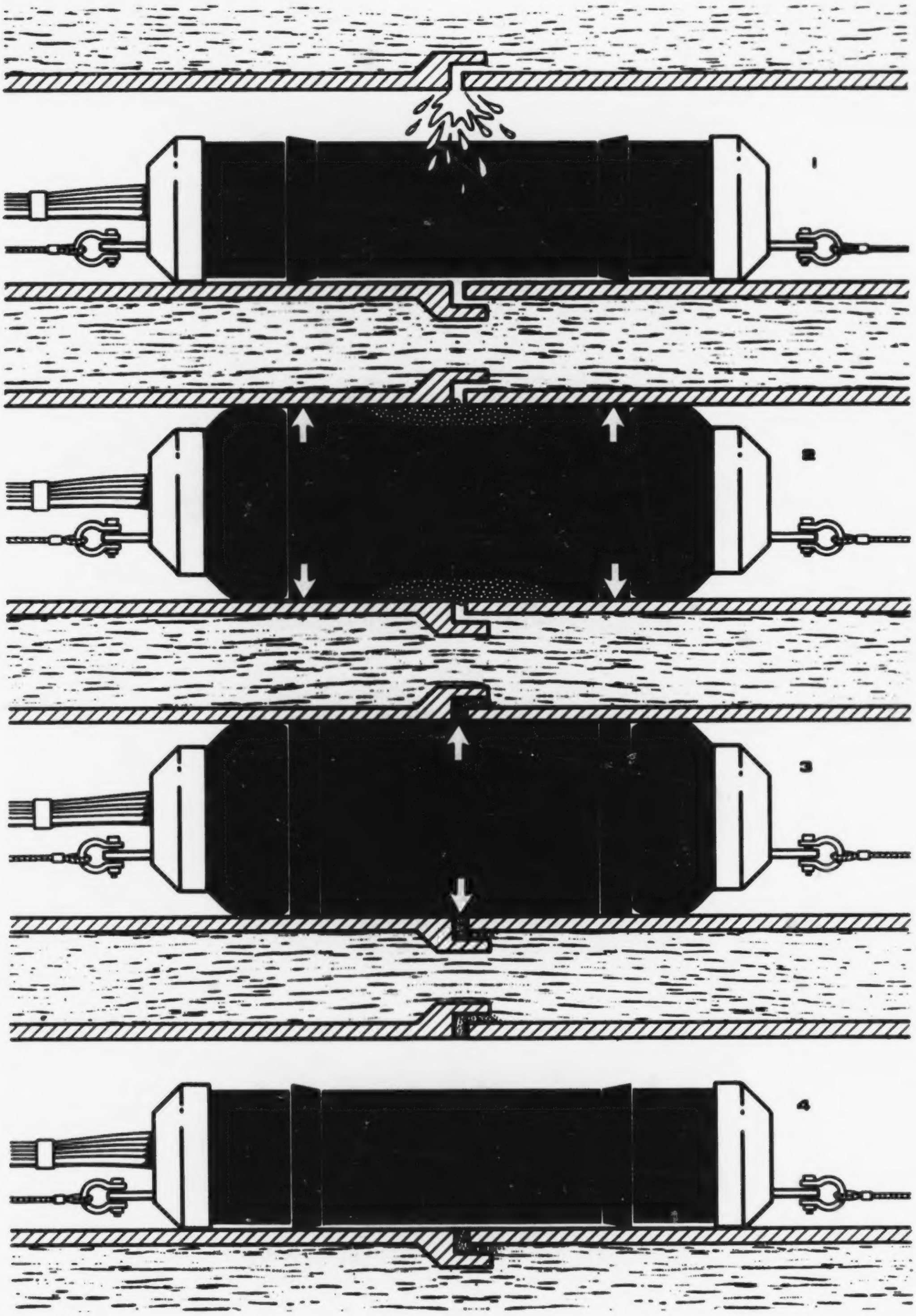
The packer is held in the inflated position until the joint is cured.

The large diameter sealing process requires a two-operator crew "down hole" to effectively run the operation (Fig. 7.45). Anytime an operator enters a large diameter pipe, the necessary safety precautions must be exercised (see Chapter 11, Section 11.2, 7. Poisonous or Toxic Gases and 8. Oxygen Deficient Atmospheres).

Large diameter chemical grout sealing is effectively used in pipes ranging in diameter from 30 to 120 inches with either bell and spigot or tongue-and-groove pipe.

Large diameter pipe sealing is a very specialized process and most work is done by contractors specializing in the process. Contact the equipment manufacturer for specific details.

A similar procedure can be used to control manhole infiltration (Fig. 7.46). A probe applicator injects the Sealant into leaky manhole walls.



Packer ball is positioned (1) and outer edges of ball inflated to isolate defective joint. Low pressure air introduced to isolated section confirms leak and grout material is inserted (2). Inflation of middle section of packer ball (3) compacts grout material to form effective seal. Packer ball is deflated (4) and moved to the next joint to be sealed.

Fig. 7.41 Operation of packer

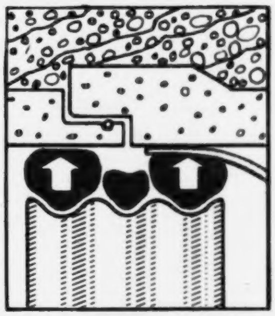


Fig. 7.42 Isolating joint

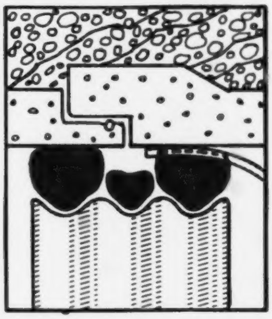


Fig. 7.43 Pumping sealing chemical

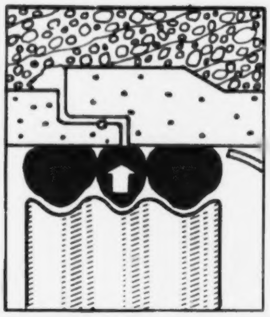


Fig. 7.44 Forcing sealing material into defective joint

7.66 Acknowledgements

All figures in this section courtesy of Cherne.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 420.

7.6D Why does the TV camera look at the packer?

7.6D Why should the TV camera be on the downstream side of the packer?

7.6F Why should only those joints that are not leaking be tested?

7.6G When can root inhibiting chemicals be used with a sealant?

7.7 GUNTING[9] SEWERS

Sewers of brick, concrete, stone and combinations of these materials can deteriorate and require repair or rehabilitation. Gunite, because of its high density, is resistant to deterioration caused by wastewater and thus is a suitable lining material to prevent further deterioration and rehabilitate sewers thirty inches in diameter and larger.

Old brick sewers in danger of collapse can be restored by properly applying gunite. Restoration by using gunite strengthens the sewer and increases flow capacity. Figure 7.47 shows an old 8-foot diameter brick sewer which was lined with two inches of reinforced gunite.

Gunite also can be shot into defective or deteriorating joints. This procedure of applying gunite to leaking joints from the inside of a sewer can effectively seal these leaks.

7.8 MANHOLE REPAIRS

Manholes must be maintained and kept in working condition just like any other structure. They must provide easy access for operators to the collection system. Frames and covers should be secure and the top at the same grade as the surrounding street or other surface. The manhole cone and barrels must be free from cracks and deterioration from corrosion. Bottom flow channels should be smooth and shelf areas should be located above the flowing wastewater, but sloped to prevent the trapping of debris during *SURCHARGE*[10] conditions.

Before scheduling any repair work on a manhole, carefully inspect the manhole (Section 5.3, Inspection of Manholes). Inspect for structural failures, cracks, corrosion damage, condition of bottom, shelves and channels, and elevation of manhole cover. When repairing a manhole, try to do all of the repair work at once.

7.81 Raising Manhole Frame and Cover to Grade

7.811 Detection of Missing Manholes

Missing manholes are sometimes buried or paved over when a street is repaved. Usually this problem is discovered by a preventive maintenance crew. If the manhole is buried in the easement (back or front yard, lawn or flower bed area), the preventive maintenance crew will locate and expose the manhole lid. Try to locate missing manholes by studyng the "as built" drawings and measuring distances from upstream and downstream manholes. Missing manholes also may be located by the use of metal detectors, ferret locators (used with hand rods or power rodders), or television. Buried railroad tracks and other metal objects can give false readings with metal detectors. The preventive maintenance crew will proceed with the work that has to be done in the manhole.

A work order is then written up with the information on the location of the manhole, and how many inches the frame and cover should be raised.

---

[9] *Gunite. A mixture of sand and cement applied pneumatically that forms a high density, resistant concrete.*

[10] *Surcharge. Sewers are surcharged when the supply of water to be carried is greater than the capacity of the pipes to carry the flow. The surface of the wastewater in manholes rises above the top of the sewer pipe, and the sewer is under pressure or a head, rather than at atmospheric pressure.*

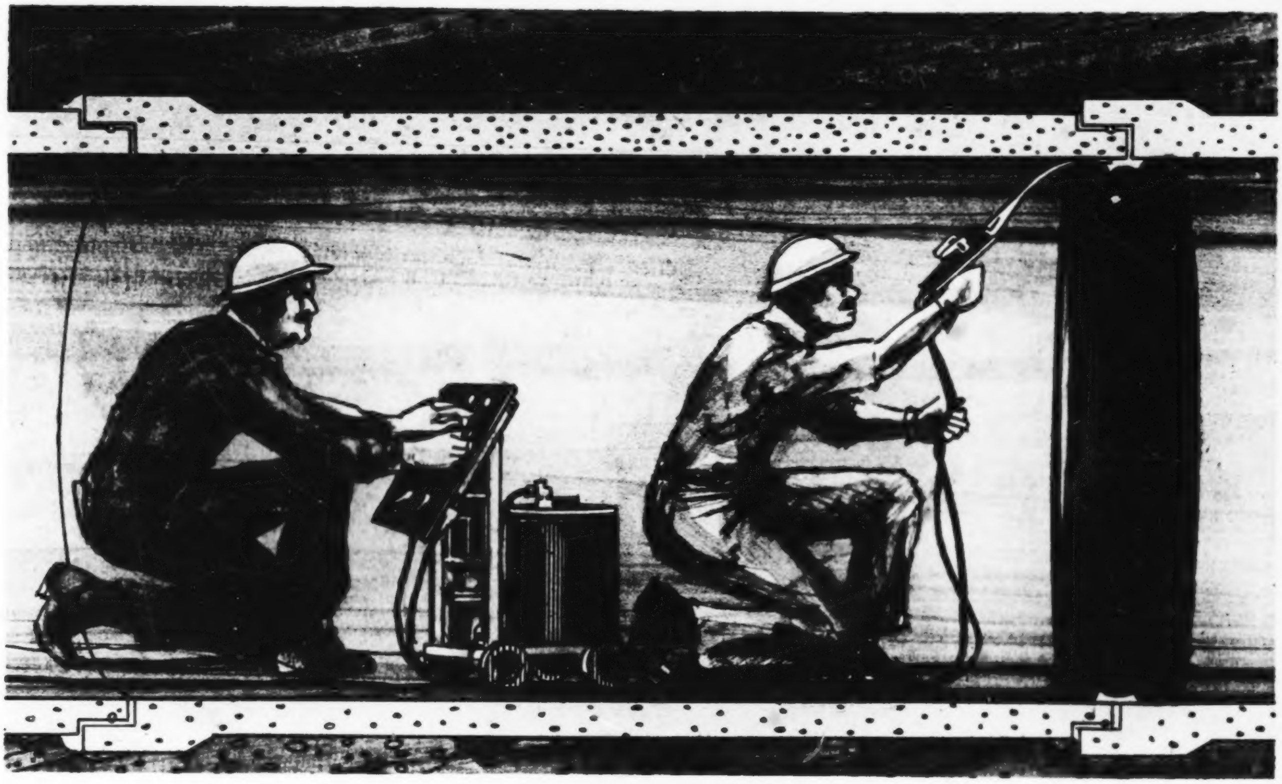


Fig. 7.45 Sealing large diameter pipe

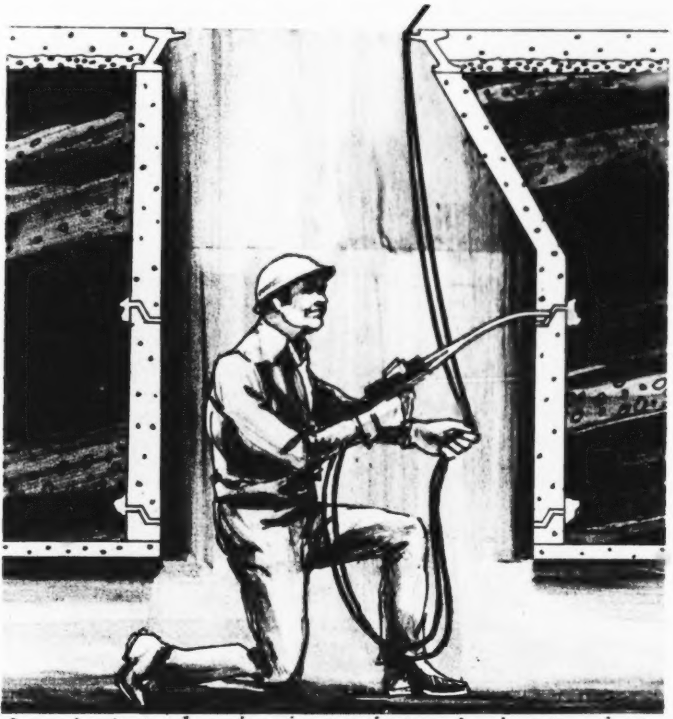
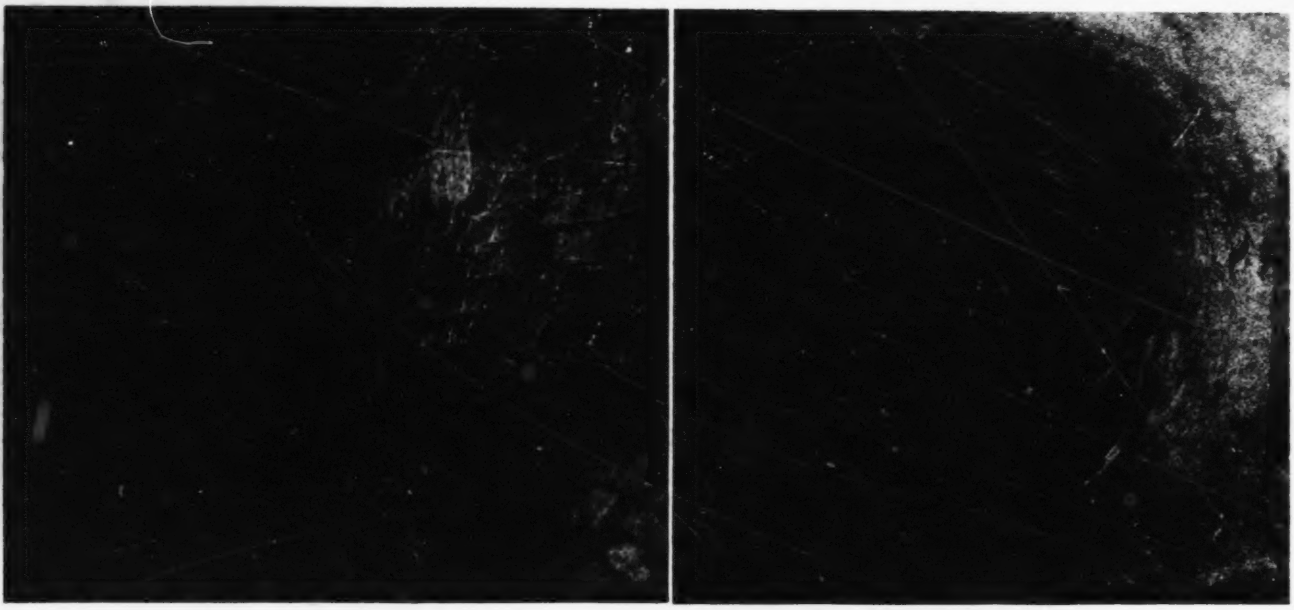


Fig. 7.46 Sealing manhole walls



7.47 Brick sewer before and after guniting
(Courtesy of Pressure Concrete Construction Company)

If the missing manhole is in the street or an alley and has been buried or paved over, the preventive maintenance crew will locate the manhole with a metal detector and mark the location with paint. If the buried manhole is not a pressing problem, the crew will again prepare a work order and turn the order over to the construction section. If the manhole is needed for immediate access, the preventive maintenance crew will contact a construction supervisor who will dispatch a crew with a compressor and jack hammer to expose and raise the manhole. The supervisor also will assist the preventive maintenance crew if needed.

7.812 Site Preparation

Once the location of the manhole to be raised is established, the following action is taken to raise a manhole in an easement:

1. Take care to remove the lawn sod, shrubs, fencing, or any other obstacles that should be replaced after the manhole has been raised and the job completed.
2. Dig down and completely expose the lid.
3. Remove lid for inspection. Be sure the casting is not offset from the grade rings or cone.
4. When the casting position has been determined, replace the lid on the casting.
5. To determine how far the manhole should be raised, use a straight rod or 2 × 4 board long enough to span the cut around the manhole. If the distance is three inches or more, a grade ring should be used. The two common ring sizes are 3 inches and 6 inches in height and are 4 inches wide.
6. Begin to remove the dirt from the outside of the casting down to the depth needed. The width of the trench around the casting should be 10 inches to 12 inches — wide enough for a round point shovel.
7. If the manhole is 12 inches or more below the surface of the yard, lawn or road, then the cut of the trench around the manhole casting may have to be 18 inches or more. This is to provide a safer working area and to provide standing room down alongside of the casting in order to lift and remove it from the hole.
8. The casting is lifted from the manhole and set aside in a safe place where it will not slide back into the hole or cave in the side of the trench. *WARNING.* Manhole castings and grade rings are very heavy and care must be exercised when lifting and moving them either by hand or with lifting equipment.
9. Clean the top of the cone or grade ring and the bottom plate of the casting. To clean these surfaces, use a wire brush and scraper. Remove all dirt and any loose cement or rust.
10. Wash all surfaces including the casting plate, both sides of the grade ring and the cone. Use water and a brush.
11. Mix the grout (suggested mix: 5 sand to 1 each cement type two). Blend to an even texture. Add water to the mixed sand and cement. Blend to the consistency you desire to maintain the slump you feel would be necessary for the thickness required by the manhole lid being raised.
12. If the rise is less than three inches, but more than one inch, manhole spacers (Fig. 7.48) should be used. Spacers may consist of small pieces of red brick, presoaked broken concrete, or small redwood blocks. These should be placed in a manner to balance the casting with the street or ground level.
13. The grade ring should be moistened on both sides just before setting the ring down on the fresh grouted cone or grade ring.
14. If the rise is more than three inches, some agencies prefer to excavate down to the manhole barrel and raise the barrel. A two-foot diameter manhole entry for any great length is very difficult to climb down or work through.

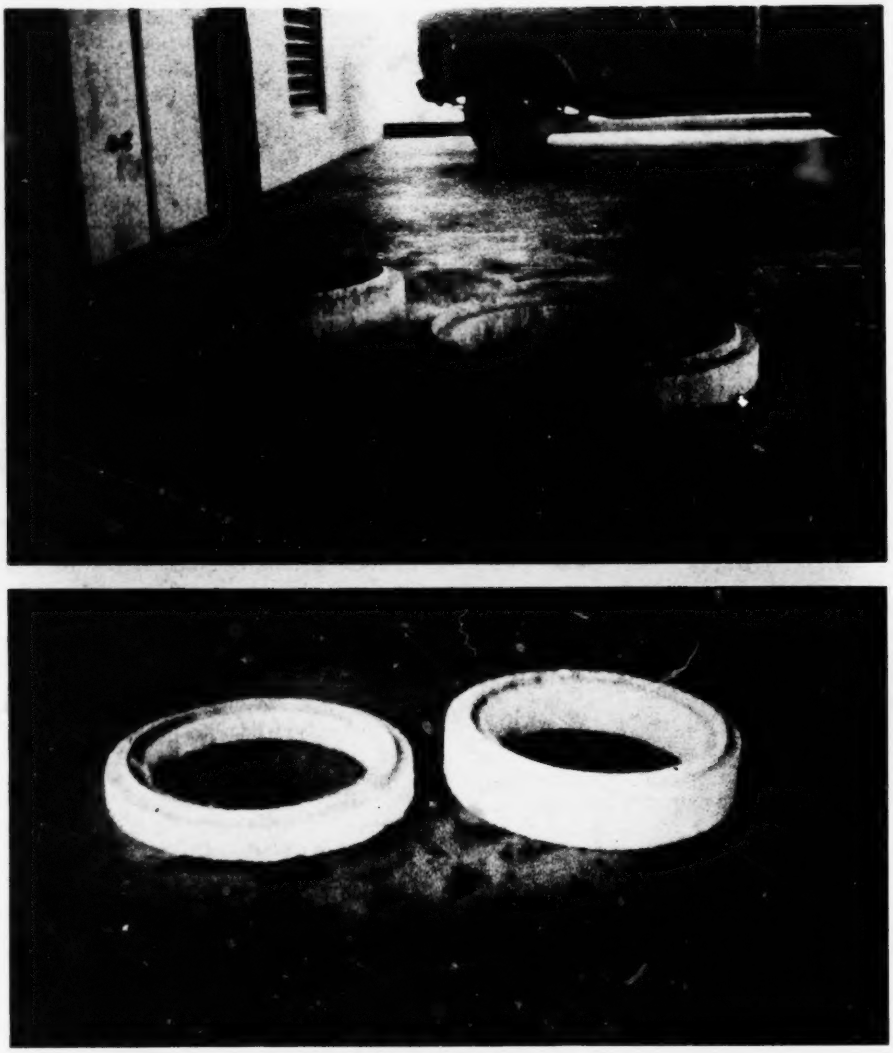


Fig 7.48 Manhole spacers

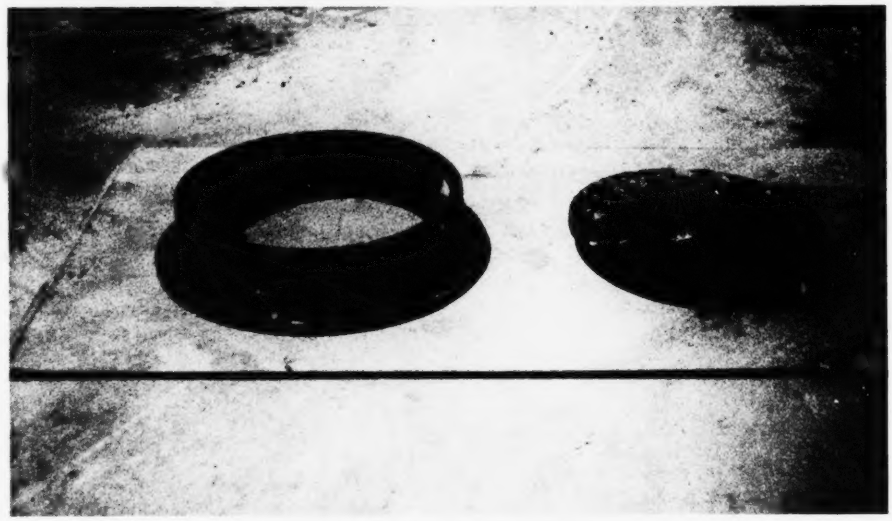


Fig. 7.49 Manhole frame and cover

7.813 Raising the Frame and Cover (Fig. 7.49)

1. One operator (Maintenance Man I) gets down alongside the cone or grade ring and using a brush or rag, wets down the cement surface. The operator is now ready for the grout.

2. The second operator (Maintenance Man I) furnishes the first operator with the grout in a shovel or a bucket. (Note: The operator placing the grout and shaping it should always wear rubber gloves for skin protection.) Place the grout around the edge with both hands, covering the complete old surface of the cone. Use your hands to form and shape the grout to the desired height. Try to keep the grout fairly uniform. Prevent all or as much excess grout as possible from falling down into the manhole by placing cover boards over the channel and shelf in the bottom of the manhole. This procedure will be repeated again when installing grade rings.

3. After the desired height of the grout has been reached, wet down the bottom of the casting plate or frame.

4. To set the casting, two operators are needed in the hole along the outside edge of the cones. Slide the casting as you pick it up from the edge of the ditch. Center it and place it on the grouted area. Make sure the casting opening is centered with the cone opening.

5. Use a straight edge to level the casting with the surrounding surface. Using a bar or sledge hammer, tap lightly on the top edge of the casting to obtain the exact level. This procedure also will squeeze out the excess grout.

6. Feather the excess grout around the casting and cone, using your hand or a brush. This should leave a smooth, clean finished surface. Remove all excess grout and place it on the outside edge between the casting and cone to form a seal from the outside. Cap the topside bottom of the casting plate with one inch of grout mix and overlap down to the cone or grade ring.

7. Backfill around the casting. After about four inches of dirt has been placed around the casting, tamp the dirt by walking on it for compaction.

8. Place the lid on the casting carefully. Continue to backfill and walk on the dirt for compaction. If backfilling more than one foot of soil, use some water to improve compaction. After backfilling and compacting, clean up excess dirt and haul it away to a disposal site.

9. Replace all lawn. Cut out an opening to keep the lid exposed. Replace shrubs in a manner that will not completely hide the lid or make it difficult to work in or around the manhole.

10. If fencing was removed, replace and cut notch out of the bottom board if it crosses the lid so the lid can be removed and replaced without any problems. Notify property owners of the notch in the fence.

Manhole lids in the street are raised following the same procedure, except we would use fast drying cement rather than sand and cement. Compaction and backfill around the manhole with air tamper or mechanical compactor to within four inches of the road level.

Use pre-packaged concrete or asphalt to fill the last four inches. Compact with an air tamper to finish grade. This procedure omits having to leave barricades in the traffic lanes. Also traffic can resume traveling over the freshly raised manhole.

Manhole lids also may be raised by excavating around the tapered cone, removing the tapered cone, frame and cover, installing a section of a reinforced concrete manhole barrel of desired length, replacing the cone section, and adjusting the frame and cover to the desired grade by using a minimum of brickwork. Sometimes manhole covers have to be raised two to three feet above grade in isolated areas to keep vandals from dumping large boulders and tree stumps into manholes.

Very often manhole lids must be raised because the manhole has settled. When manholes settle, sewers connected to a manhole may crack or break and the connection joints may develop leaks. Repair these problems when raising manhole lids and conducting other manhole repairs.

Industry has developed a special manhole casting which fits into existing lids and can be adjusted vertically to correct grade. This casting allows manhole covers to be raised before streets are paved and can be tilted if the pavement slopes.

Concrete collars are frequently used around the castings of manholes located in easements and streets. The collar may be six inches or more wide and extend to a depth of a foot or more so that it bonds to the cone section of the manhole. This collar will protect the casting of manholes located in fields from being damaged by farm equipment.

Asphalt may be placed to depths greater than four inches (up to 12 to 18 inches) in streets. The asphalt is tamped in four inch lifts and produces a dense, well compacted asphalt against the cone section of the manhole up to the street level. This procedure usually eliminates cracking and water damage of the street surface at the casting.

If the manhole barrel and cone sections must be removed and replaced, adjust and seal the joints with a bituminous rubbery material commercially available in different widths and thicknesses. Set the material over the grove section of the manhole barrel and then place the tongue section on top of the material to push the material into the grove. This material provides a totally impervious joint, does not have shrinkage problems and requires much less time than the use of grout or mortar to connect and seal new sections of manhole barrels. Use mortar to set the grade ring and casting.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 421.

7.8A Why do the lids of manholes have to be raised?

7.8B How are paved-over manholes located?

7.8C How is the height the manhole should be raised determined?

7.5D When the casting is lifted from the manhole, where should it be placed?

7.8E How can the top of the cone or grade ring be cleaned?

7.8F Why should the operator placing the grout and shaping it wear rubber gloves?

7.8G What should be done with fences over manholes?

7.82 Repair of Manhole Bottoms

Most manhole repair problems are discovered by preventive maintenance crews and are assigned to the repair section for correction in the form of work orders. This section describes procedures for inspecting and repairing manhole bottoms.

After all safety precautions have been taken by the three-operator crew and the manhole has been purged with fresh air, the manhole is washed down from the casting down to and including the bottom. This will usually clear the walls of material such as mud, grease, or other debris. Washing also helps clean out spiders, centipedes and other annoying pests. Run the blower at all times when there is an operator working in the manhole (See Chapter 11, Section 11.2, 7. Poisonous or Toxic Gases, and 8. Oxygen Deficient Atmospheres).

After washing is completed, one operator (Maintenance Man I) will enter the manhole with proper safety equipment using a secure ladder. Inspect the casting, grade rings, cone, and barrels for seepage, deterioration and cracks. Once on the manhole bottom, inspect the condition of the channel to determine what action will have to be taken to correct any flow or leakage problems.

Problems encountered at the bottom of manholes range from *NO BOTTOM* to improper channels such as flat bottom, basin bottom and low inflow invert elevation to high outflow invert elevation that causes a sump or backwater problem. These problems are usually found in older sections of a wastewater collection system.

The following is a list of methods that can be used to correct each type of problem.

7.821 Manholes Without Concrete Bottoms

To start repair, if possible, plug off all incoming lines. If not possible, bridge a channel or channels across manhole bottom to allow flow to continue. Use half pieces of thin metal forms or plastic pipe to provide channels. Once channels are in place, probe the bottom to determine how much debris will have to be removed. Remove as much of the liquid portion of waste as possible in a bucket and remove from manhole for hauling off to a disposal site. Clear enough depth in bottom of the manhole for at least two and if possible, three feet of cobble stone, approximately four inches in diameter, for base fill. Leave at least a ten-inch space below form or the bottom of pipes to provide a firm footing. Be careful the manhole doesn't start to settle.

Cover cobble rock with four inches of crushed rocks (¾-inch to dust). After all this has been done and base is determined to be solid, inspect forms and make any necessary adjustments.

Spray rock base with water. Mix concrete to suitable slump. Pour the base by starting under the forms and carefully tamping under and up the side of the forms. This should prevent honeycombs and pockets. Once this is done, continue to pour until you have reached the amount needed to complete one side of the shelf and channel. The shelf slope should drop at least one inch and not more than 2 inches from the back wall of manhole to the top of the edge of the channel.

Place a knee board over finished shelf to stand on while pouring the rest of the manhole bottom. When the remainder of the bottom is finished, carefully stand on or in the pipe channel form. Remove knee board and touch up lightly by brushing entire bottom to remove the trowel marks and produce a brush or broom finish. Forms should not be removed for a least 36 to 48 hours to allow time for the concrete to harden and cure. After allotted time, remove forms and inspect the channels for any honeycombs. If honeycombs are observed, use quick setting cement to fill void areas.

To reduce the need for forms to shape the channel bottom, cut a section of plastic pipe or other type of sewer pipe in half to fit the invert and cement it into place. Advantages of this procedure include having a smooth flow channel and not having to worry about the concrete channel deteriorating and causing turbulence which can release odors.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 421.

7.8H Why should manhole walls be washed before inspection?

7.8I What types of problems are encountered at the bottom of manholes?

7.8J What is the first step to start repair of a manhole with no bottom?

7.8K What kind of base is provided in the bottom of a manhole without a concrete bottom?

7.8L Why should the concrete surface on the bottom of a manhole be brushed or broomed?

7.822 Manholes With Flat Bottoms

Flat bottom manholes do not have channels through the bottom and are fairly easy to correct because the base is already in place.

1. First plug off all incoming lines, if possible. Another approach is to install a smaller pipe with the ends of the pipes sealed to the ends of the manhole inflow and outflow pipes in order to carry flow through the manhole. Clean, scrape and brush the bottom.

2. Remove plug or plugs, form channel with half pieces of tin, plastic pipe forms, or half sections of sewer pipe and repeat process from "no bottom manhole". Start with the procedure for pouring concrete and follow the steps with pouring to the finishing of the concrete. Remove forms 48 hours later if half sections of sewer pipe were not used.
3. Step 2 above may be replaced by use of speed-crete, once the plug or plugs are removed, the speed-crete can be used to form and shape the new channels. This process is by far the fastest and more practical procedure, with the exception of using half sections of sewer pipe.
4. Now that the channels are formed and set, start with a speed-crete and pea-gravel mixture. Mix to same consistency as concrete. Pour and trowel to desired finish. Pea-gravel is used to reduce the amount of speed-crete which would usually be needed and makes the fill-in stronger.

   NOTE: Speed-crete is not a cement. It is aluminum and plastics and has a much higher resistance to acids and sulfide that makes this a much more practical material to use in building manhole bottoms.

   Pour the mixture to the desired height, usually 2 inches above the top of the pipes. Shape and finish one side. Now stand in the formed channel and pour and finish the shelves of the manhole.

7.823 Channel Corrections

Channel corrections are made to relieve flow problems such as the tee-shaped channel. This type channel is called "dead-heading", which means the flow runs directly into the main channel flow. This causes a turbulent flow and can restrict the flow from incoming lines.

Tee-intersections can be corrected by cutting off one corner of the tee-shaped channel. Use a jack hammer and cut down below the flow line. Use speed-crete and reshape the channel into a smooth wye shape. This will channel the flow in the same direction as the main flow.

Basin channels are usually found on incomplete channel bottoms. This channel usually starts 6 to 12 inches from the wall of the manhole and then feathers out into the basin. The flow correction again can be made by forming speed-crete for the proper channel shape. Fill in behind the new channel with a speed-crete and pea gravel mixture. Form the shelves of the manhole too.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 421.

7.8M How are channels formed using speed-crete?

7.8N How are smooth channel surfaces obtained when using speed-crete?

7.8O Why does speed-crete have a higher resistance to acids and sulfide than concrete?

7.8P Why are channel corrections made?

7.8Q How are channel corrections made?

7.83 Inside Drop in Manholes (Fig. 7.50)

A main line or house service line lateral entering the manhole at a higher elevation than the main flow line or channel causes splashing, odors and difficult working conditions. These lines should have inside drop pipes connected to them. The inside drop line consists of a tee attached to the incoming pipe and should fit flush against the manhole wall. A length of pipe runs from the tee to the manhole bottom and a 90-degree elbow directs the flow into the channel at the correct angle. If possible, service lines should be connected to manholes as outside drops, but inside drops are more economical after the system is completed.

7.831 Materials Used for Inside Drops

The most suitable pipe and fittings used for all inside drop lines into a manhole up to twelve inches in diameter is plastic class 125 pipe. The class 125 plastic pipe has worked very successfully for inside drop lines. Examples of use include from 4 inch up to 12 inch inside drop lines, including discharge drops at the end of force mains.

7.832 Materials Used for Inside Drops

1. Use a jack hammer, drill hammer and chisel to chip out concrete around the incoming pipe and back into the wall of the manhole at least 2½ inches. Set the tee fitting into the opening at a vertical angle. The tee should line up with the pipe and fit tight against the wall.
2. Set a plumb line to the manhole bottom shelf to determine where the 90-degree angle will set. If possible, use the jack hammer and cut a channel with the proper angle to insure correct flow with flow in the main channel.
3. Measure the distance from the tee to the 90-degree angle to determine the length of pipe needed. Glue fittings to the pipe and set in place. Recheck for alignment. Use speed-crete to cement the tee into the wall, to anchor the 90-degree angle into place, and to finish the new channel. The tee should be strapped to the wall. If the drop pipe is more than 8 feet, this pipe also should be strapped to the wall of the manhole.
4. Force main discharge drop lines should always be double strapped to the wall around the tee fitting or a sanitary tee. The 90-degree angle at the bottom of the drop line should be channeled in as close to the flow line as possible to prevent any spray or splash.

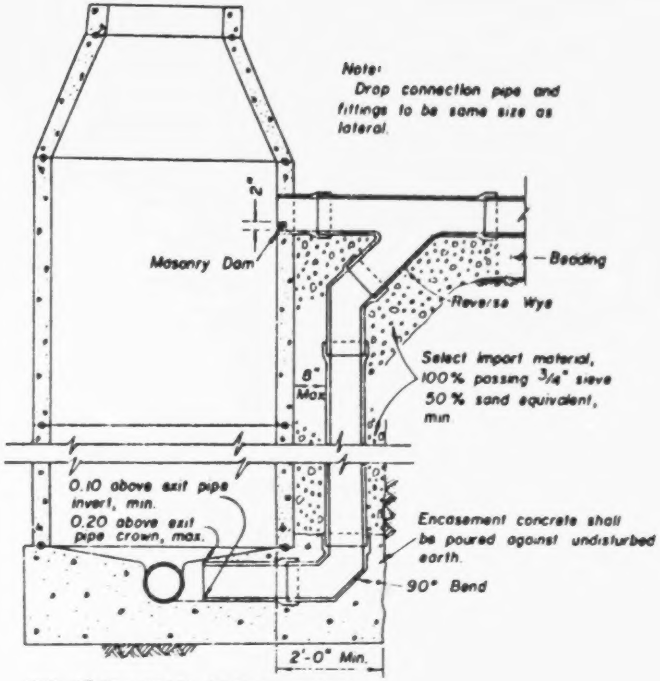
7.84 Repair of Manhole Barrels

Repair of a manhole barrel depends on what is wrong with the manhole, the condition of the manhole, and the circumstances under which the repairs must be made. To repair cracks or leaks in a manhole barrel, several techniques are available:

1. Patching,
2. Grouting, and
3. Lining.

Patching is done with a fast-drying cement and usually under adverse or wet conditions. Grouting also uses a fast-drying cement. The grout is either applied by hand or sprayed over the surface being repaired.

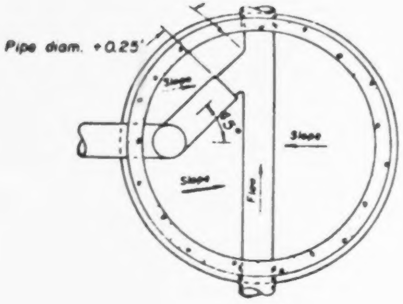
Lining a manhole consists of either inserting a liner or spraying a lining material over the manhole barrel. A piece of pipe can be inserted in a manhole as a liner. The pipe could be made of plastic, tile or bricks. Grout is placed in the space between the manhole and the pipe. A liner such as epoxy or fiberglass may be sprayed over a manhole barrel. The surface of the barrel must be dry before spraying.


Note:
Drop connection pipe and fittings to be same size as lateral.
2"
Masonry Dam
Beading
Reverse Wye
8" Max
Select import material, 100% passing 3/4" sieve 50% sand equivalent, min
0.10 above exit pipe invert, min.
0.20 above exit pipe crown, max.
Encasement concrete shall be poured against undisturbed earth.
90° Bend
2'-0" Min.

FOR 10" OR LARGER DROP OR WHERE SPECIFICALLY INDICATED ON THE DRAWINGS

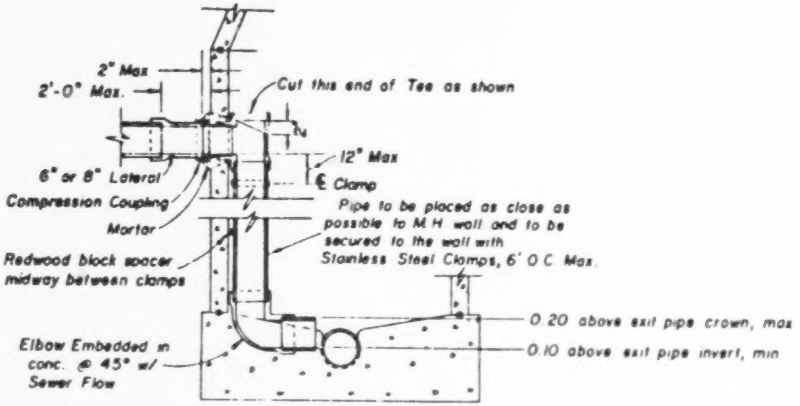
OUTSIDE DROP CONNECTION

NOTE: Some agencies use a tee instead of a reverse wye for ease in getting at or into the drop from the manhole.


Pipe diam. + 0.25'
Slope
45°
Slope
Slope
Flow

PLAN

NOTE:
1. All inside drop piping to be P.V.C. or Mod. Styrene.
2. Cement all joints.
3. Drop connection pipe and fittings to be same size as lateral.
4. Clamps to be 1½" × 12 ga stainless steel, anchored to M.H. wall with 2½" cadmium plated bolts.


2" Max
2'-0" Max.
Cut this end of Tee as shown
12" Max
℄ Clamp
6" or 8" Lateral
Compression Coupling
Mortar
Pipe to be placed as close as possible to M.H. wall and to be secured to the wall with Stainless Steel Clamps, 6' O.C. Max.
Redwood block spacer midway between clamps
0.20 above exit pipe crown, max
0.10 above exit pipe invert, min
Elbow Embedded in conc. @ 45° w/ Sewer Flow

PROFILE

INSIDE DROP CONNECTION

Fig. 7.50 Inside and outside drop connections

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 421.

7.8R What is an inside drop line?

7.8S Why are inside drop lines installed in manholes?

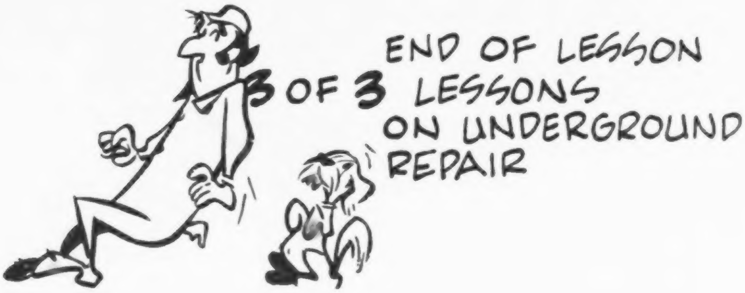
7.8T How are inside drop lines secured?

7.8U What material is used for inside drop lines?

7.9 NEW CONSTRUCTION

Occasionally a crew may be required to extend a line a short distance and install a new cleanout or manhole. The procedures for new installations are similar to repairs, except usually the problems created by wastewater flowing in the existing system are not present.

For additional information on new construction procedures, read Chapter 3, SUPPLEMENT, on construction, inspection and testing.



DISCUSSION AND REVIEW QUESTIONS

Chapter 7. UNDERGROUND REPAIR

(Lesson 3 of 3 Lessons)

Write the answers to these questions in your notebook before continuing to the Objective Test on page 422. The problem numbering continues from Lesson 2.

13. Why are sewers grouted or chemically sealed?
14. How would you seal a leaky joint in an 8-inch sewer?
15. How would you clean up after a sealing operation?
16. What types of repairs are likely to be needed by manholes?
17. How would you raise the lid or cover of a manhole?
18. How would you repair a manhole without a concrete bottom?

SUGGESTED ANSWERS

ANSWERS TO QUESTIONS IN LESSON 1

Answers to questions on page 374.

7.1A Underground repair and new construction are very hazardous because of the threat of cave-ins and dangerous gases.

7.1B Underground repairs are necessary to replace damaged pipe or to remove difficult obstructions.

7.1C Underground damages may be discovered by homeowners when the collection system fails, by emergency crews attempting to clear a stoppage, or by an inspector of a preventive maintenance crew.

7.1D Underground repair may be required if damage to pipe or stoppages are caused by roots, cracked pipe, protruding taps, improper taps and damage by the public, other utilities or construction activities.

7.1E A work request form notifies a foreman or crew leader and the crew of a repair job. The form specifies what is to be done and the job location. The foreman or crew leader and supervisor plan and schedule work on the basis of information on work request forms and other needs.

7.1F Before starting a repair job, a foreman should visit the job site and plan the job. Potential conflicts with traffic, utilities and other obstructions should be noted. Other utility agencies should locate their underground facilities. Property owners should be notified. Also a preconstruction and tail gate safety meeting should be held before starting the job.

Answers to questions on page 376.

7.2A Shoring requirements depend on depth of trench, width of trench, soil conditions, nearby activities and the laws and regulations.

7.2B Lack of shoring or shoring failure is the number one cause of cave-in deaths.

7.2C Shoring systems in trenches consist of some form of sheeting or liner, uprights held rigidly opposite each other against the trench walls by jacks or horizontal cross members (braces) and, if required, longitudinal members (stringers).

7.2D Uprights shall extend as near to the bottom of the trench as permitted by the material being installed, but not more than 2 feet from the bottom.

7.2E Soil stability may be classified as hard compact, running or unstable.

Answers to questions on page 378.

7.2F All excavation work shall at all times be under the immediate supervision of someone with authority to modify the shoring system or work methods as necessary to provide adequate safety.

7.2G Spoils or excavated material must be placed two feet or more back from the edge of the trench. If the trench is over 5 feet deep, spoil must be placed more than 4 feet back from the edge of the trench.

7.2H All trenches deeper than *5* feet must be shored.

7.2I If shoring is not practical, the sides or walls of an excavation may be sloped.

7.2J Walkways must be provided for pedestrians to keep them out of the way and from being injured.

Answers to questions on page 393.

7.2K Different types of common shores include:

1. Hydraulic,
2. Screw Jacks,
3. Air,
4. Solid Sheeting,
5. Cylinder, and
6. Shield.

7.2L The main advantages of hydraulic shores are their ease of installation and they can be installed by one operator.

7.2M The main advantages of screw jacks are that they are inexpensive to purchase and are practical for minor repairs in smaller excavations. A limitation is that they are time consuming to install.

7.2N Solid sheeting must be installed when excavation is in material that will not stand vertical and because of location, it is not practical to slope the trench.

7.2O Material is excavated in small cylinder shoring by hand using a shovel. In cylinders with a large enough diameter, material can be removed mechanically.

7.2P Cylinder shoring is used when the working area is small and only a small portion of the main line must be exposed.

7.2Q Shield shoring is used during excavation and installation of various types of sewers in areas and soil conditions that present a combination of problems.

7.2R The major concern during a shoring operation is the protection of the operators. Assume all trenches and excavations are unsafe.

ANSWERS TO QUESTIONS IN LESSON 2

Answers to questions on page 397.

7.3A Repair assignments must be made in writing in order to maintain records and provide a history of who made what repairs, when, where, how and why.

7.3B Upon receipt of a work order request, examine existing records to determine if the problem has occurred in the past. During the preliminary field investigation, alert the homeowner and look for any unusual problems that may exist such as trees or shrubs that could get in the way.

7.3C Before a crew drives to a repair job, all safety equipment should be inspected and the truck should contain the proper equipment, materials and tools to do the job.

7.3D Upon arrival at the job site, verify that the address and map location are correct. Place traffic cones at front and rear of truck in accordance with local regulations. Notify property owner and discuss care of any plants or trees that may have to be moved.

Answers to questions on page 400.

7.3E Placing soil from an excavation on a canvas protects the grass and allows for easier shoveling of soil back into excavation.

7.3F When excavating to repair a sewer line, be careful not to damage or break other utility lines. Also use shoring if necessary to prevent cave-ins. Ventilation equipment should be available and used when necessary.

7.3G After a pipe is cut, carefully remove section so you don't get cut on sharp edges of pipe and be sure inside of pipe is clear before installing cleanout.

7.3H Use gravel or sand and crushed rock in the bottom of the trench for bedding of wye.

7.3I Before backfilling trench, inspect job, tighten all couplings or seal joints, and be sure there are no tools remaining in ditch.

7.3J A service line location card must be completed to provide a record of location of cleanout for future reference.

7.3K The crew leader should review job with foreman when it is completed. Any potential problem areas should be discussed so foreman can communicate with homeowner or supervisors.

Answers to questions on page 401.

7.4A Before a crew is assigned a main line repair job, the foreman makes a preliminary field investigation to identify potential problems and to plan the repair job. The foreman marks the repair area with paint and meets with representatives of utility agencies at the job site.

7.4B The foreman needs other utility agencies to indicate location and depth of their utilities at the job site.

7.4C Before the crew starts the job, the foreman and crew chief review a map of the job site, the proper procedures and safety precautions, and the necessary equipment, tools and materials.

7.4D Before leaving the yard for the job site, the crew should inspect all equipment (including safety) and determine that all the necessary equipment, tools and materials needed to do the job are loaded on the trucks.

7.4E When arriving on the job site, the crew should carefully park the trucks, prepare traffic control and contact homeowners and owners of parked vehicles. If parked vehicles are a potential problem, the job site can be barricaded and marked the night before or very early in the morning.

Answers to questions on page 404.

7.4F Before cutting the street, the crew should verify the location of the repair area by measuring the distances from the upstream and downstream manholes.

7.4G Unidentified utilities may be located by watching for changes in soil texture or other signs that could indicate the presence of cross trenches.

7.4H Usually spoils from an excavation are suitable for backfill because the material comes from an old backfill.

7.4I Keep the spoils pile at least four feet from edge of trench if the trench is over 5 feet deep and, if shallower, spoil must be at least 2 feet from edge of trench.

7.4J By use of an extension probe determine the elevation of the line being repaired.

7.4K The backhoe can dig to within six inches of the main line.

7.4L Lower equipment and material into the trench using a bucket and rope.

7.4M All loose dirt should be removed from under the main line to prevent a muddy mess and to provide room for gravel to form the bedding material for the pipe.

7.4N The backfill is usually compacted by mechanical tampers instead of water jetting in roads and streets.

7.4O The job site is protected by barricades with flashers until the patching crew arrives.

Answers to questions on page 404.

7.5A Future problems which are caused by the settling of backfill in an excavation being spanned can be avoided by proper bedding. Dig on each side of the excavation being crossed so that there is at least 18 inches of good, solid undisturbed soil for the spliced in DIP or PVC C-900 pipe to rest on with proper bedding.

7.5B Crushed rock should be used as bedding for sewers spanning excavations.

7.5C Ductile iron pipe (DIP) and polyvinylchloride (PVC C-900) water pipe are installed when sewer lines cross the excavations or trenches of other utilities.

Answers to questions on page 406.

7.6A Grouting or sealing can be considered as a possible means of repairing or rehabilitating sewers when the sewers are in an area that is unsuitable for excavation and is either infiltrating or exfiltrating through leaking joints, cracks or small holes. Sealing processes also are used on new construction of sewer lines where the contractor is unable to pass the line acceptance test.

7.6B The basic pieces of sealing equipment include the air compressor, chemical pump, water pump, control panel and sleeve packer.

7.6C Desirable properties of chemical grout sealants include:

1. Resistance to most organic solvents, mild acids and alkali,
2. Returns to shape after repeated deformations,
3. Essentially non-toxic in cured form,
4. Does not become rigid or brittle when exposed to freeze-thaw or dry or low moisture conditions, and
5. Noncorrosive and does not contain neurotoxic ingredients in either cured or uncured form.

Answers to questions on page 410.

7.6D The TV camera looks at the packer so the sealing operation can be observed.

7.6E The TV camera should be on the downstream side of the packer because the upstream water build up cuts valuable time from the operation and obscures much of the visual inspection of the process.

7.6F Leaky joints don't have to be tested because they have to be sealed anyway.

7.6G Root inhibiting chemicals can be used with a sealant only after the roots in the sewer and joints have been killed and removed.

Answers to questions on page 415.

7.8A Manhole lids should be raised when they are below ground level or they are paved over when a street is repaved. Below grade manholes are difficult to locate and may be subject to surface inflow.

7.8B Paved over manholes can be located by examining "as built" drawings and measuring distances from upstream and downstream manholes, by using a metal detector or by the use of a TV camera.

7.8C To determine the height the manhole lid should be raised, place a straight rod or 2 × 4 board across the cut around the manhole and measure the distance from ground level to the manhole lid.

7.8D Place the casting from the manhole a safe distance away where it won't slide back into the hole or cave in the side of the trench.

7.8E Clean the top of the grade ring or cone using a wire brush or scraper.

7.8F The operator placing and shaping the grout should wear rubber gloves to protect exposed skin.

7.8G If a fence was over a manhole whose lid was raised, replace the fence and cut a notch out of the bottom board so the lid can be removed. Notify property owners.

Answers to questions on page 415.

7.8H Manhole walls should be washed before inspection to clear the walls of material such as mud, grease, or other debris. Washing also helps clean out spiders, centipedes and other annoying pests.

7.8I Problems encountered at the bottom of manholes include no bottom, flat bottom, basin bottom, low incoming invert elevation to high outgoing invert elevation that causes a sump problem, improper channels, and disjointed pipe junctions.

7.8J To start repair of a manhole with no bottom, either plug off all incoming lines and pump wastewater to a downstream manhole, or bridge a channel or channels across the manhole bottom to allow flow to continue.

7.8K The base in the manhole should consist of cobble rock and crushed rock for the new concrete bottom.

7.8L Brush the concrete surface on the bottom of a manhole to prevent a slick surface.

Answers to questions on page 416.

7.8M Channels are formed by hand when using speed-crete.

7.8N Smooth channel surfaces can be obtained using speed-crete by wiping down the walls with a wet rag or wet sponge.

7.8O Speed-crete has a higher resistance to acids and sulfide than concrete because it consists of aluminum and plastics.

7.8P Channel corrections are made to correct flow problems and produce smooth flow through the manhole.

7.8Q Channel corrections are made by removing obstructions or poor channels with jack hammers and reshaping or providing new channels using speed-crete.

Answers to questions on page 418.

7.8R An inside drop line consists of a tee, pipe and 90-degree angle installed in a manhole to divert water from an incoming line to the main flow channel at the bottom of the manhole.

7.8S Inside drop lines are installed in manholes to stop splashing, odors, and difficult working conditions

7.8T Inside drop lines are strapped to manhole walls.

7.8U Plastic class 125 pipe is used for inside drop lines.

OBJECTIVE TEST

Chapter 7. UNDERGROUND REPAIR

Please mark correct answers on answer sheet as directed at the end of Chapter 1. There may be more than one correct answer to each multiple choice question.

TRUE-FALSE

1. Underground work can be very hazardous.
   1. True
   2. False
2. A blockage in a sewer line due to grease requires that the line be dug up for repair.
   1. True
   2. False
3. All utility companies in an area should be notified before attempting to dig up and repair a sewer.
   1. True
   2. False
4. Operators installing cross braces in trenches should start at the bottom and work upward.
   1. True
   2. False
5. Broken and collapsed pipes can be repaired by the use of proper cleaning techniques.
   1. True
   2. False
6. Sealing of leaking joints usually stops all infiltration.
   1. True
   2. False

MULTIPLE CHOICE

7. Hazards encountered by operators when repairing a sewer line include
   1. Cave-ins.
   2. Dangerous gases.
   3. Falling objects.
   4. Fires.
   5. Traffic.
8. Important safety considerations when repairing sewer lines include protecting
   1. Operators from injury.
   2. Operators from traffic.
   3. Other utilities.
   4. Private property.
   5. Public from injury.
9. Wastewater collection system repairs are necessary to
   1. Correct damage to pipe.
   2. Fix sealed joints.
   3. Improve straight pipe gradients.
   4. Prevent inflow and infiltration.
   5. Remove an obstruction.
10. Sewer lines may have to be dug up because they are damaged or blocked due to
    1. Grease.
    2. Improper taps.
    3. Roots.
    4. Underground construction.
    5. Vandalism.
11. Shoring requirements depend on
    1. Depth of trench.
    2. Nearby activities.
    3. Soil conditions.
    4. Type of soil.
    5. Width of trench.
12. The person in charge at a sewer line trenching job is responsible for
    1. Clearing stoppages.
    2. Public relations.
    3. Routing traffic.
    4. Sewer line maintenance.
    5. Shoring system.
13. Keeping spoil away from the edge of the trench tends to reduce the
    1. Chance of knocking tools into the excavation.
    2. Damage to trenching equipment.
    3. Height of the spoil pile.
    4. Load on side walls.
    5. Opportunity for someone to trip and fall into the excavation.
14. Before starting an underground sewer repair job, other companies with underground utilities in the area must be contacted to
    1. Check on the availability of their equipment for assistance.
    2. Determine how long it's been since they dug up the street.
    3. Have these companies mark the location of their utilities in the area of the repair job.
    4. See if they want to help route traffic while you are doing the repair job.
    5. Verify if they have some excavating to do in the area too.
15. Soil stability may be classified as
    1. Creeping.
    2. Hard compact.
    3. Loose.
    4. Running.
    5. Unstable.
16. Type of shores include
    1. Air shores.
    2. Hydraulic shores.
    3. Screw jacks.
    4. Solid sheeting.
    5. Water shores.

17. Angle of repose means angle of slope of
    1. Cut.
    2. Drainage ditch.
    3. Sewer.
    4. Trench excavation.
    5. Unsupported loose soil.

18. Sewer repair assignments to crews must be made in writing in order to
    1. Bill persons causing need for repairs.
    2. Document when repairs were performed.
    3. Maintain records.
    4. Provide a history of who made what repairs.
    5. Record weather conditions.

19. If utilities are encountered in the excavation of a trench,
    1. Cut each utility line open so the proper utility can be notified of the location of its line.
    2. Dig around the utilities and notify the utility company to come out and provide support for its lines.
    3. Remove the utilities so they won't be a safety hazard while you are working.
    4. Support the utilities so they won't crack or break.
    5. Turn the utility lines off so they won't cause problems if they are accidentally broken.

20. Potential problems that need to be identified by a foreman before starting the repair of a main line include
    1. Destroying any trees that could interfere with the operation of a crane.
    2. Determining elevation of groundwater.
    3. Locating buried utilities in area of repair site.
    4. Routing traffic around job site.
    5. Saving section of removed pipe for future repairs.

21. To prepare for cutting a sewer pipe, the repairman in the trench must be wearing
    1. Gloves.
    2. Safety glasses.
    3. Safety harness.
    4. Self-contained breathing apparatus.
    5. Steel toe rubber knee boots.

22. After arriving at the job site to repair a sewer in an easement, the following tasks should be completed before the repair (excavation) is started.
    1. Conduct a meeting to review safety and construction procedures.
    2. Identify any plants or shrubs that have to be transplanted or replaced.
    3. Notify the homeowner.
    4. Place traffic cones on traffic side of truck at front and rear of truck.
    5. Verify address and location of repair job.

23. Main line repairs should be made when
    1. A new and better type of pipe is developed.
    2. A permanent stoppage occurs.
    3. Grease blocks the line.
    4. The line continuously develops stoppages due to problems caused by the pipe or in the pipe.
    5. The pipe deteriorates.

24. When repairing a main line, the depth of the main line can be determined by
    1. Determining depth from plans, digging to within 18 inches, and then using a probe.
    2. Digging until the pipe is hit with the backhoe.
    3. Digging with a pick and shovel.
    4. Opening a manhole and observing depth to top of pipe.
    5. Using a level.

25. Additional supporting strength for concrete joints for sewers spanning excavations can be provided by
    1. Additional water.
    2. Concrete netting.
    3. Less cement.
    4. Reinforcing bars.
    5. Stucco netting.

26. Techniques commonly used to repair cracks or leaks in a manhole barrel include
    1. By-passing.
    2. Grouting.
    3. Lining.
    4. Patching.
    5. Replacing.

27. Missing manholes that were buried when a street was repaved may be located by
    1. Looking for dips in the pavement surface.
    2. Sending a TV camera down the sewer.
    3. Studying "as built" drawings and measuring from upstream and downstream manholes.
    4. Tapping pavement with a hammer.
    5. Using a metal detector.

28. What items are inspected in a manhole to determine if repairs are needed in the manhole?
    1. Barrels for cracks
    2. Barrels for seepage
    3. Bottom channel
    4. Cone for deterioration
    5. Level of grease line

29. Types of manhole *REPAIRS* may include
    1. Correcting bottom channels.
    2. Installation of inside drops.
    3. Killing insects and rodents.
    4. Raising frame and cover to grade.
    5. Washing down sides and shelves.

30. Internal sealing is effective when the sewer line to be repaired has
    1. Broken pipe.
    2. Collapsed sections.
    3. Cracks.
    4. Leaking joints.
    5. Small holes.

31. Sealing or grouting may be used when
    1. An area is unsuitable for excavation.
    2. The sewer can't be televised.
    3. There is exfiltration through cracks.
    4. There is infiltration and exfiltration through small holes.
    5. There is infiltration through joints.

32. Grout sealing chemicals should have the following properties:
    1. Becomes rigid or brittle when exposed to wet conditions.
    2. Resistance to acids and alkalis.
    3. Resistance to organic solvents.
    4. Returns to shape after repeated deformations.
    5. Toxic in cured form.

REVIEW QUESTIONS

33. Traffic safety requires collection system operators to consider
    1. Driving to job site.
    2. Parking vehicles at job site.
    3. Placing signs and barricades around job site.
    4. Routing pedestrians around job site.
    5. Routing traffic around job site.
34. Before entering a manhole, collection system operators must consider
    1. Lowering equipment and tools into manhole.
    2. Routing traffic.
    3. Testing the manhole atmosphere.
    4. Using safety harness and lifeline.
    5. Ventilating manhole.

END OF OBJECTIVE TEST

FINAL EXAMINATION
AND
SUGGESTED ANSWERS
FOR
OPERATION AND MAINTENANCE OF WASTEWATER COLLECTION SYSTEMS
VOLUME I

FINAL EXAMINATION
VOLUME I

This final examination was prepared *TO HELP YOU* review the material in this manual. The questions are divided into four types:

1. True-false,
2. Multiple choice,
3. Short answer, and
4. Problem.

To work this examination:

1. Write the answer to each question in your notebook.
2. After you have worked a group of questions (you decide how many), check your answers with the suggested answers at the end of this exam, and
3. If you missed a question and don't understand why, reread the material in the manual.

You may wish to use this examination for review purposes when preparing for civil service and certification examinations.

Since you have already completed this course, you do not have to send your answers to California State University, Sacramento.

True-False

1. Better trained and motivated collection system operators are essential to present a case for improved priorities and public recognition regarding collection systems.
   1. True
   2. False
2. Flooded basements from backed up sewers can cause cross connections between wastewater and the public water supply.
   1. True
   2. False
3. Collection system operators spend most of their time working in manholes.
   1. True
   2. False
4. Confined spaces are a safe place to work.
   1. True
   2. False
5. Sewer pipes must have rigid joints.
   1. True
   2. False
6. When laying sewer pipe, the bell end of the pipe should be upstream.
   1. True
   2. False
7. Excessive velocities of wastewater flowing in sewers can cause the release of odors.
   1. True
   2. False
8. Clothing worn in a manhole may be worn at home after work.
   1. True
   2. False
9. Common practice is to pull the TV camera from the downstream manhole to the upstream manhole.
   1. True
   2. False
10. The local fire department must be thoroughly briefed on a smoke testing operation before it is started.
    1. True
    2. False
11. After cleaning a large septic stoppage, be sure to notify the operator on duty at the downstream wastewater treatment plant.
    1. True
    2. False
12. When adding water to a manhole from a fire hydrant for a balling operation, air gap devices are required to prevent any backflow of wastewater from a manhole to a drinking water supply.
    1. True
    2. False
13. When operating a high velocity cleaner, the nozzle should be stopped at a heavy grease deposit until the grease is washed away.
    1. True
    2. False
14. Never use rubber gloves while handling or guiding a sewer rod that is turning.
    1. True
    2. False
15. Chemical treatment usually is a permanent solution for most odor problems.
    1. True
    2. False

16. Before starting to dig up and repair a sewer, property owners in the area should be contacted to make them aware of any inconvenience that might occur.
    1. True
    2. False

17. Operators installing shoring do not have to worry about cave-ins.
    1. True
    2. False

Multiple Choice

1. Where can collection operators look for more information on training courses to improve themselves?
    1. Colleges and universities
    2. Federal, state and local water pollution control agencies
    3. Libraries
    4. State and local water pollution control associations
    5. Water Pollution Control Federation

2. A flexible sewer pipe material or joint is necessary to withstand
    1. Construction disturbances.
    2. Corrosion.
    3. Earth movement.
    4. Surcharged flows.
    5. Vibration from traffic.

3. What questions should be asked and answered during a review of plans and specifications and a field investigation of a new intercepting sewer?
    1. Are easements large enough?
    2. Can the system be easily operated and maintained?
    3. How can repairs be made in case of failures?
    4. Is the route or alignment satisfactory?
    5. Is there sufficient overhead clearance?

4. Potential impacts of smoke testing on the occupants of a building include
    1. Asphyxiation.
    2. Discovery of smoke from a defective wax ring under a commode.
    3. Exposure to smoke from a vent that was terminated in an attic.
    4. Gas poisoning.
    5. Smoke encountered from a missing clean out plug.

5. Smoke tests are conducted to find the location of
    1. Broken sewers.
    2. Illegal connections.
    3. Lost manholes.
    4. Sources of surface inflow.
    5. TV camera wedged or caught in sewer.

6. When balling a sewer and the ball suddenly stops, this is an indication of
    1. A large deposit.
    2. Sufficient material has built up to stop the ball.
    3. The ball hitting a bad tap.
    4. The ball reaching the next manhole.
    5. The pull winch operator at the downstream manhole stopping the pulling of the ball.

7. Roots growing into sewers may be removed from sewers by the use of
    1. Balling.
    2. Flushing.
    3. Power rodders.
    4. Pumping.
    5. TV cameras.

8. Before applying any chemicals to a sewer, which of the following items must be done?
    1. Be able to take the proper action if an accident occurs.
    2. Know how to mix and apply the chemical.
    3. Read the label on the chemical container.
    4. Study chemistry.
    5. Understand the type of chemical reaction that will occur.

9. Sewers can be damaged or blocked by
    1. Improper taps.
    2. Kites.
    3. Manholes between sewers.
    4. Roots.
    5. Underground construction damaging the sewer.

10. What items are inspected in a manhole to determine if repairs are needed in the manhole?
    1. Barrels for cracks
    2. Barrels for seepage
    3. Bottom of channel
    4. Cone for deterioration
    5. Level of grease line

Short Answer

1. What do the letters O & M mean?
2. Why are collection system agencies similar to other utility agencies?
3. Define
    a. Gravity flow.
    b. Infiltration.
4. What are collection systems expected to achieve?
5. Why do sewers require a flexible pipe material or joint that can maintain tightness?
6. Define backflow preventer.
7. Why should collection system operators be able to identify sources and quantities of wastewater flow?
8. Define olfactory fatigue.
9. Why should wastewater collection systems be inspected and tested?
10. Why should exfiltration be controlled?
11. What is a rotameter?
12. List the three main objectives of a sewer cleaning and maintenance program.
13. How can homes be flooded by sewer cleaning crews?
14. What precautions should be taken when working around cable operated equipment?

15. Which rodding clearing tool would you select to rod a pipe when conditions in the sewer are unknown?
16. What happens when roots growing in a sewer are cut?
17. What problems are created by the presence of hydrogen sulfide?
18. What does the term "surcharge" mean?
19. What should a foreman do before starting a sewer repair job in a street?
20. Under what conditions must solid sheeting be used?
21. What cautions should be exercised when excavating to repair a sewer line?

Problem

1. A float travels 450 feet between two manholes in 150 seconds. Estimate the velocity of the wastewater flowing in the sewer. Assume the float travel time is the same as the time for the flowing wastewater.

SUGGESTED ANSWERS FOR FINAL EXAMINATION

True-False

1. True Better trained and motivated collection system operators are essential to present a case for improved priorities and public recognition regarding collection systems.
2. True Flooded basements from backed up sewers can cause cross connections between wastewater and the public water supply.
3. False Modern technology has developed tools and equipment which significantly reduce the time collection system operators must spend in manholes.
4. False Confined spaces are a dangerous place to work. The atmosphere must be continuously monitored for explosive conditions, toxic gases and oxygen deficiencies.
5. False Sewer joints must be flexible to withstand movement and remain airtight.
6. True When laying sewer pipe, the bell end of the pipe should be upstream.
7. True Excessive velocities of wastewater flowing in sewers can cause the release of odors.
8. False After working in a manhole, always change your clothes before going home.
9. False Common practice is to pull the TV camera from the upstream to the downstream manhole.
10. True The local fire department must be thoroughly briefed on a smoke testing operation before it is started.
11. True Always notify the operator on duty at the downstream wastewater treatment plant after cleaning a large septic stoppage.
12. True Air gap devices are required to prevent any backflow of wastewater from a manhole to a drinking water supply during any sewer maintenance job.
13. False When operating a high velocity cleaner, always keep the nozzle moving up or down the sewer so it won't become stuck.
14. True Never use rubber gloves while handling or guiding a sewer rod that is turning because the rod could seize the palm of the glove and cause an injury.
15. False For a permanent solution to odor problems, try to correct the source of the odor rather than using chemicals to control the odor.
16. True Before starting to dig up and repair a sewer, always notify the property owners to make them aware of any inconvenience that might occur.
17. False Operators installing shoring must worry about cave-ins.

Multiple Choice

1. 1,2,3,4,5 Collection system operators may look for more information on training courses to improve themselves under all of the sources listed.
2. 1,3,5 A flexible sewer pipe material or joint is necessary to withstand construction disturbances, earth movement, and vibration from traffic.
3. 1,2,3,4,5 Questions asked should include questions regarding size of easements, ease of operation and maintenance, ability to make repairs in case of failures, satisfactory route or alignment, and sufficient overhead clearance.
4. 2,3,5 Potential impacts of smoke testing on the occupants of a building include the discovery of a defective wax ring under a commode, a vent terminated in an attic and a missing cleanout plug. Smoke used for testing should not cause asphyxiation or gas poisoning.
5. 1,2,3,4 Smoke testing is conducted to find the location of broken sewers, illegal connections, lost manholes and sources of surface inflow.

6. 1,2,3 When a sewer ball suddenly stops in a sewer, this could be an indication of (1) a large deposit, (2) sufficient material has built up to stop the ball, and (3) the ball hitting a bad tap.

7. 3 Power rodders may be used to remove roots growing into sewers.

8. 1,2,3,5 Before applying any chemicals to a sewer, (1) be able to take proper action if an accident occurs, (2) know how to mix and apply the chemical, (3) read the label on the chemical container, and (5) understand the type of chemical reaction that will occur.

9. 1,4,5 Sewers can be damaged or blocked by improper taps, roots and underground construction damaging the sewer.

10. 1,2,3,4 Items that should be inspected to determine if repairs are needed in a manhole include (1) barrels for cracks, (2) barrels for seepage, (3) bottom of channel and (4) cone for deterioration.

Short Answer

1. The letters O & M stand for Operation and Maintenance.
2. Collection system agencies are similar to other utility agencies because
   (1) collection systems must be operated and maintained, and
   (2) the public expects the system to work without failure (at all times).
3. Define
   a. *GRAVITY FLOW*. Water or wastewater flowing from a higher elevation to a lower elevation due to the force of gravity. The water does not flow due to energy provided by a pump. Wherever possible, wastewater collection systems are designed to use the force of gravity to convey waste liquids and solids.
   b. *INFILTRATION*. The water entering a sewer system and service connections from the ground. Defective pipes, pipe joints, connections or manhole walls are a few of the common locations where infiltration may occur.
4. Collection systems are expected to carry our wastewater away from our homes and industries to the wastewater treatment plant.
5. Flexible materials and joints are necessary to withstand earth movement, vibration from traffic, settling of structures and construction disturbances and tightness is necessary to prevent root intrusion.
6. Define *BACKFLOW PREVENTER*. A device used to stop the accidental backflow of wastewater into buildings by either allowing backflowing wastewater to flow out of a building sewer at a point lower than the building plumbing fixtures (overflow type) or by blocking the backflow to the building sewer by a one-way flapper seal (check valve type).
7. Collection system operators should be able to identify sources and quantities of wastewater flow in order to identify and correct causes of collection system stoppages and maintenance problems.
8. Olfactory fatigue is a condition in which a person's nose, after exposure to certain odors, is no longer able to detect the odor.
9. Wastewater collection systems should be inspected and tested to
   1. Identify existing and potential problem areas,
   2. Evaluate seriousness of detected problems,
   3. Locate position of problems, and
   4. Provide clear, concise, and meaningful reports to supervisors regarding problems.
10. Exfiltration must be controlled because it can cause pollution of groundwater.
11. A rotameter is a device used to measure the flow rate of gases and liquids. The gas or liquid being measured flows vertically up a calibrated tube. Inside the tube is a small ball or a bullet-shaped float (it may rotate) that rises or falls depending on the flow rate. The flow rate may be read on a scale behind the middle of the ball or the top of the float.
12. The three main objectives of a sewer cleaning and maintenance program are to minimize the number of
    1. Stoppages per mile of sewer,
    2. Odor complaints, and
    3. Lift station failures.
13. Homes can be flooded by hydraulic sewer cleaning crews by carelessness. The maximum level of water in a sewer or manhole (used to maintain head on a balling or similar type of cleaning operation) must always be below the lowest plumbing fixture in a home that the water could reach.
14. When working around cable operated equipment, keep your hands clear of the drum. Use a manhole hook to guide the cable. In an instant, your hand or fingers can become entangled and the operator cannot stop the machine fast enough to avoid injury.
15. A round-stock corkscrew is a first-step cleaning tool for rodding where conditions are unknown.
16. When roots in a sewer are cut, the roots will send out new growth just back from the cutting. Also the root will increase in diameter and break the pipe or open up the joint even more.
17. Problems created by hydrogen sulfide include
    1. Paralysis of the respiratory center and death of operators,
    2. Rotten egg odors,
    3. Corrosion and possible collapse of sewers, structures and equipment, and
    4. Loss of capacity of sewer.
18. *SURCHARGE*. Sewers are "surcharged" when the supply of water to be carried is greater than the capacity of the pipes to carry the flow. The surface water in manholes rises above the top of the sewer pipe, and the sewer is under pressure or a head, rather than at atmospheric pressure.
19. Before starting a sewer repair job in a street, a foreman should visit the job site and plan the job. Potential conflicts with traffic, utilities and other obstructions should be noted. Other utility agencies should locate their underground facilities. Property owners should be notified. Also a preconstruction and tail gate safety meeting should be held before starting the job.

20. Solid sheeting must be installed when excavation is in material that will not stand vertical and because of location, it is not practical to slope the trench.

21. When excavating to repair a sewer line, notify other utility agencies and be careful not to damage or break other utility lines. Also use shoring if necessary to prevent cave-ins. Ventilation equipment should be available and used when necessary.

Problem

1. Estimate the average velocity in a sewer.

KNOWN	UNKNOWN
Distance, ft = 450 feet	Velocity, ft/sec
Time, sec = 150 sec	

Calculate the average velocity.

$$\text{Velocity, ft/sec} = \frac{\text{Distance, ft}}{\text{Time, sec}}$$

$$= \frac{450\text{ ft}}{160\text{ sec}}$$

$$= 3\text{ ft/sec}$$

COLLECTION SYSTEM WORDS

by

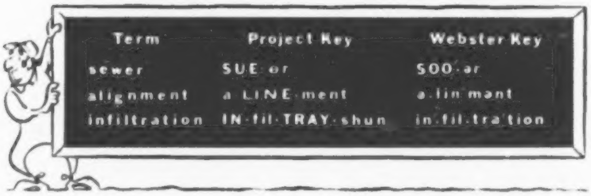
George Freeland

OPERATOR'S PROJECT PRONUNCIATION KEY

by Warren L. Prentice

The Operator's Project Pronunciation Key is designed to aid you in the pronunciation of new words. While this Key is based primarily on familiar sounds, it does not attempt to follow any particular pronunciation guide. This Key is designed solely to aid operators in this program.

You may find it helpful to refer to other available sources for pronunciation help. Each current standard dictionary contains a guide to its own pronunciation Key. Each Key will be different from each other and from this Key. Examples of the differences between the Key used in this program and the Webster's New World Dictionary Key, Second College Edition, 1972[1] are shown below:



Term	Project Key	Webster Key
sewer	SUE·er	SOO·ar
alignment	a·LINE·ment	a·lin·mant
infiltration	IN·fil·TRAY·shun	in·fil·tra'tion

In using this Key, you should accent (say louder) the syllable which appears in capital letters. The following chart is presented to give examples of how to pronounce words using the Operator's Project Key.

	Syllable			
	1st	2nd	3rd	4th
Word				
Sewer	SUE	er		
Alignment	a	LINE	ment	
Infiltration	IN	fil	TRAY	shun

The first word, sewer, has its first syllable accented. The second word, alignment, has its second syllable accented. The third word, infiltration, has its first and third syllables accented.

We hope you will find the Key useful in unlocking the pronunciation of any new word.

EXPLANATION OF WORDS

The meanings of words in the glossary of this manual are based on current usage by the wastewater collection profession and definitions given in *GLOSSARY — WATER AND WASTEWATER CONTROL ENGINEERING*, prepared by the Joint Editorial Board representing APHA, ASCE, AWWA and WPCF,* 1981. Certain words used by wastewater collection system operators tend to have slightly different meanings in some regions of the United States. We have tried to standardize word meanings as much as possible.

**APHA. American Public Health Association.*
ASCE. American Society of Civil Engineers.
AWWA. American Water Works Association.
WPCF. Water Pollution Control Federation.

---

[1] *The Webster's New World Dictionary, Second College Edition, 1972 was chosen rather than an unabridged dictionary because of its availability to most collection system operators.*

GLOSSARY

A

ABANDONED (a-BAN-dund) ABANDONED

No longer in use; a length, section or portion of a collection system no longer in service and left in place, underground. For example, when a house or building is razed or removed the service connection may be left open and unused.

ABATEMENT (a-BAIT-ment) ABATEMENT

Putting an end to an undesirable or unlawful condition affecting the wastewater collection system. A property owner found to have inflow sources connected to the collection system may be issued a "NOTICE OF ABATEMENT." Such notices will usually describe the violation, suggest corrective measures and grant a period of time for compliance.

ABSORPTION (ab-SORP-shun) ABSORPTION

The taking in or soaking up of one substance into the body of another by molecular or chemical action (as tree roots absorb dissolved nutrients in the soil).

ABSORPTION CAPACITY ABSORPTION CAPACITY

The amount of liquid which a solid material can absorb. Sand, as an example, can hold approximately one third of its volume in water, or three cubic feet of dry sand can contain one cubic foot of water. A denser soil, such as clay, can hold much less water and thus has a lower absorption capacity.

ABSORPTION RATE ABSORPTION RATE

The speed at which a measured amount of solid material can absorb a measured amount of liquid. Under pressure, water can infiltrate a given volume of gravel very rapidly. The water will penetrate (or be absorbed by) sand more slowly and will take even longer to saturate the same amount of clay.

AEROBIC (AIR-O-bick) AEROBIC

A condition in which "free" or dissolved oxygen is present in the aquatic (water) environment.

AIR BLOWER AIR BLOWER

A device used to ventilate manholes and lift stations.

AIR GAP AIR GAP

An open vertical drop, or vertical empty space, between a drinking (potable) water supply and the point of use. This gap prevents back siphonage because there is no way wastewater can reach the drinking water. Air gap devices are used to provide adequate space above the top of a manhole and the end of the hose from the fire hydrant. This gap insures that no wastewater will flow out the top of a manhole, reach the end of the hose from a fire hydrant, and be sucked back up the hose to the water supply.

AIR TEST AIR TEST

A method of inspecting a sewer pipe for leaks. Inflatable or similar plugs are placed in the line and the space between these plugs is pressurized with air. A drop in pressure indicates the line or run being tested has leaks.

AIR TEST, QUICK AIR TEST, QUICK

(See QUICK AIR TEST)

ALIGNMENT (a-LINE-ment) ALIGNMENT

The proper positioning of parts in a system. The alignment of a pipeline or other line refers to its location and direction.

ALLUVIAL DEPOSIT (a-LOU-vee-al) ALLUIVIAL DEPOSIT

Sediment (clay, silt, sand, gravel) deposited in place by the action of running water.

ALTERNATING CURRENT (A.C.) ALTERNATING CURRENT (A.C.)

An electric current that reverses its direction (positive/negative values) at regular intervals.

AMBIENT AMBIENT

Surrounding. Ambient or surrounding atmosphere.

AMPERAGE (AM-purr-age) AMPERAGE

The strength of an electric current measured in amperes.

AMPERE (AM-peer) AMPERE

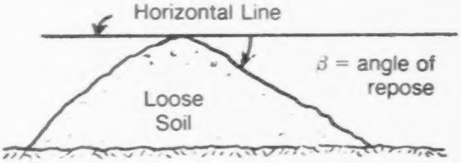
The unit used to measure current strength. The current produced by an electromotive force of one volt acting through a resistance of one ohm.

ANAEROBIC (AN-air-O-bick) ANAEROBIC

A condition in which "free" or dissolved oxygen is *NOT* present in the aquatic (water) environment.

ANGLE OF REPOSE ANGLE OF REPOSE

The angle between a horizontal line and the slope or surface of unsupported material such as gravel, sand, or loose soil. Also called the "natural slope."



ANIMAL WASTES ANIMAL WASTES

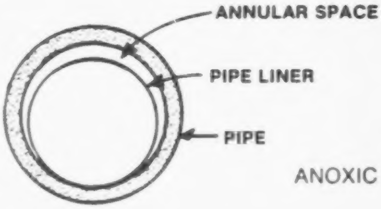
(1) Urine and fecal wastes of living animals.

(2) Wastes of animal tissue from meat processing (feathers included), hospital, surgical and clinical facility wastes of animal types.

(3) Similar to (2) above, but cooked or prepared wastes of animal tissues and bones from domestic or commercial food preparation.

ANNULAR SPACE (AN-ul-are) ANNULAR SPACE

A ring-shaped space. For example, the space between the outside of a pipe liner and the inside of a pipe.



ANOXIC ANOXIC

Oxygen deficient or lacking sufficient oxygen.

APARTMENT COMPLEX APARTMENT COMPLEX

One or more residential buildings at a single location. An apartment building may contain several residences with a single connection to the wastewater collection system. A complex can have several buildings with a single connection.

APPURTENANCE (a-PURR-ten-nans) APPURTENANCE

Machinery, appliances, structures and other parts of the main structure necessary to allow it to operate as intended, but not considered part of the main structure.

AQUIFER (ACK-wi-fer) AQUIFER

A porous, water-bearing geologic formation. Usually refers only to materials capable of yielding a substantial amount of water.

ARCH ARCH

The curved top of a sewer pipe or conduit.

ARTIFICIAL GROUNDWATER TABLE ARTIFICIAL GROUNDWATER TABLE

A groundwater table that is changed by artificial means. Examples of activities that artificially raise the level of a groundwater table include agricultural irrigation, dams and excessive sewer line exfiltration. A groundwater table can be artificially lowered by sewer line infiltration, water wells, and similar drainage methods.

ASPHYXIATION (ass-FIX-ee-a-shun) ASPHYXIATION

An extreme condition often resulting in death due to a lack of oxygen and excess carbon dioxide in the blood from any cause. Also called suffocation.

AUGER (AW-grr) AUGER

A sharp tool used to go through and break up or remove various materials that become lodged in sewers.

B

BACKFILL BACKFILL

(1) Material used to fill in a trench or excavation.

(2) The act of filling a trench or excavation, usually after a pipe or some type of structure has been placed in the trench or excavation.

BACKFILL, BORROW BACKFILL, BORROW

(See BORROW)

BACKFILL COMPACTION BACKFILL COMPACTION

(1) Tamping, rolling or otherwise mechanically compressing material used as backfill for a trench or excavation. Backfill is compressed to increase its density so that it will support the weight of machinery or other loads after the material is in place in the excavation.

(2) Compaction of a backfill material can be expressed as a percentage of the maximum compactability, density or load capacity of the material being used.

BACKFILL, SELECT BACKFILL, SELECT

(See SELECT BACKFILL)

BACKFLUSHING BACKFLUSHING

A procedure used to wash settled waste matter off upstream structures to prevent odors from developing after a main line stoppage has been cleared.

BACKHOE BACKHOE

An excavating machine whose bucket is rigidly attached to a hinged stick on a boom and is drawn toward the machine during excavation.

BACKWATER GATE BACKWATER GATE

A gate installed at the end of a drain or outlet pipe to prevent the backward flow of water or wastewater. Generally used on storm sewer outlets into streams to prevent backward flow during times of flood or high tide. Also called a TIDE GATE.

BACTERIA (back-TEAR-e-ah) BACTERIA

Bacteria are living organisms, microscopic in size, which consist of a single cell. Most bacteria use organic matter for their food and produce waste products as a result of their life processes.

BALLING BALLING

A method of hydraulically cleaning a sewer or storm drain by using the pressure of a water head to create a high cleansing velocity of water around the ball. In normal operation, the ball is restrained by a cable while water washes past the ball at high velocity. Special sewer cleaning balls have an outside tread that causes them to spin or rotate, resulting in a "scrubbing" action of the flowing water along the pipe wall.

BAR RACK BAR RACK

A screen composed of parallel bars, either vertical or inclined, placed in a sewer or other waterway to catch debris. The screenings may be raked from it.

BARREL BARREL

(1) The cylindrical part of a pipe that may have a bell on one end.

(2) The cylindrical part of a manhole between the cone at the top and the shelf at the bottom.

BEDDING BEDDING

The prepared base or bottom of a trench or excavation on which a pipe or other underground structure is supported.

BEDDING COMPACTION BEDDING COMPACTION

(1) Tamping, rolling or otherwise mechanically compressing material used as bedding for a pipe or other underground structure to a density that will support expected loads.

(2) Bedding compaction can be expressed as a percentage of the maximum load capacity of the bedding material.

(3) Bedding compaction also can be expressed in load capacity of pounds per square foot.

BEDDING DESTRUCTION BEDDING DESTRUCTION

Loss of grade, load capacity or material of a bedding.

BEDDING DISPLACEMENT BEDDING DISPLACEMENT

Bedding which has been removed after placement and compaction. In a sewer pipe system, this can take place as a result of washouts due to infiltration, earth shifts or slides, damage from nearby excavations and/or improper backfill methods.

BEDDING FAULTS BEDDING FAULTS

Locations where bedding was improperly applied and thus failed.

BEDDING GRADE BEDDING GRADE

(1) In a gravity-flow sewer system, pipe bedding is constructed and compacted to the design grade of the pipe. This is usually expressed in a percentage. A 0.5 percent grade would be a drop of one-half foot per hundred feet of pipe.

(2) Bedding grade for a gravity-flow sewer pipe can also be specified as elevation above mean sea level at specific points.

BEDDING, MANHOLE BEDDING, MAHOLE

(See MANHOLE BEDDING)

BEDDING MATERIAL, SELECT BEDDING MATERIAL, SELECT

(See SELECT BEDDING)

BELL BELL

(1) In pipe fitting, the enlarged female end of a pipe into which the male end fits. Also called a HUB.
(2) In plumbing, the expanded female end of a wiped joint.

BELL-AND-SPIGOT JOINT BELL-AND-SPIGOT JOINT

A form of joint used on pipes which have an enlarged diameter or bell at one end, and a spigot at the other which fits into and is laid in the bell. The joint is then made tight by lead, cement, rubber "O" ring, or other jointing compounds or materials.

BELLMOUTH BELLMOUTH

An expanding, rounded entrance to a pipe or orifice.

BEND BEND

A piece of pipe bent or cast into an angular shape.

BIOCHEMICAL OXYGEN DEMAND (BOD) BIOCHEMICAL OXYGEN DEMAND (BOD)

The rate at which microorganisms use the oxygen in water or wastewater while stabilizing decomposable organic matter under aerobic conditions. In decomposition, organic matter serves as food for the bacteria and energy results from its oxidation.

BIT BIT

(1) Cutting blade used in rodding (pipe clearing) operations.

(2) Cutting teeth on the auger head of a sewer boring tool.

BLOCKAGE BLOCKAGE

(1) Partial or complete interruption of flow as a result of some obstruction in a sewer.

(2) When a collection system becomes plugged and the flow backs up, it is said to have a "blockage."

Commonly called a STOPPAGE.

BLOWER BLOWER

A device used to ventilate manholes and lift stations.

BLUEPRINT BLUEPRINT

A photographic print in white on a bright blue background used for copying maps, mechanical drawings, construction plans and architects' plans.

BOD (BEE-OH-DEE) BOD

Biochemical Oxygen Demand. The rate at which microorganisms use the oxygen in water or wastewater while stabilizing decomposable organic matter under aerobic conditions. In decomposition, organic matter serves as food for the bacteria and energy results from its oxidation.

BORROW BACKFILL BORROW BACKFILL

Material used for backfilling a trench or excavation which was not the original material removed during excavation. This is a common practice where tests on the original material show it to have poor compactability or load capacity. Also called IMPORTED BACKFILL.

BRACES BRACES

(See CROSS BRACES)

BRANCH MANHOLE BRANCH MANHOLE

A sewer or drain manhole which has more than one pipe feeding into it. A standard manhole will have one outlet and one inlet. A branch manhole will have one outlet and two or more inlets.

BRANCH SEWER BRANCH SEWER

A sewer that receives wastewater from a relatively small area and discharges into a main sewer serving more than one branch-sewer area.

BREAK BREAK

A fracture or opening in a pipe, manhole or other structure due to structural failure and/or structural defect.

BRICKWORK BRICKWORK

A structure made of brick, such as in older sewers.

BRINELLING BRINELLING

This type of bearing failure appears as tiny indentations (dents) high on the shoulder of the race.

BROKEN HUB BROKEN HUB

In bell-and-spigot pipe, the bell portion is frequently called the "hub." A fracture or break in the bell portion is called a "broken hub."

BROKEN SECTION BROKEN SECTION

A run of pipe between two joints is referred to as a "section." A fracture in a section is called a "broken section."

BUCKET BUCKET

(1) A special device designed to be pulled along a sewer for the removal of debris from the sewer. The bucket has one end open with the opposite end having a set of jaws. When pulled from the jaw end, the jaws are automatically opened. When pulled from the other end, the jaws close. In operation, the bucket is pulled into the debris from the jaw end and to a point where some of the debris has been forced into the bucket. The bucket is then pulled out of the sewer from the other end, causing the jaws to close and retain the debris. Once removed from the manhole, the bucket is emptied and the process repeated.

(2) A conventional bail is used in BUCKETING OUT.

BUCKET BAIL BUCKET BAIL

The pulling handle on a bucket machine.

BUCKET MACHINE BUCKET MACHINE

A powered winch machine designed for operation over a manhole. The machine controls the travel of buckets used to clean sewers.

BUCKETING OUT BUCKETING OUT

An expression used to describe removal of debris from a manhole with a pail on a rope. In balling or high-velocity cleaning of sewers, debris is washed into the downstream manhole. Removal of this debris by scooping it into pails and hauling debris out is termed "bucketing out."

BUILDING SERVICE BUILDING SERVICE

A saddle or "Y" connection to a lateral or branch sewer for connection of a building lateral.

BUILDING SEWER BUILDING SEWER

A gravity-flow pipeline connecting a building wastewater collection system to a lateral or branch sewer. The building sewer may begin at the outside of the building's foundation wall or some distance (such as 2 to 10 feet) from the wall, depending on local sewer ordinances. Also called a HOUSE CONNECTION or a SERVICE CONNECTION.

BUILDING WASTEWATER COLLECTION SYSTEM BUILDING WASTEWATER COLLECTION SYSTEM

All of the wastewater drain pipes and their hardware that connect plumbing fixtures inside or adjacent to a building to the building sewers. This includes traps, vents and clean-outs.

BY-PASS BY-PASS

A pipe, valve, gate, weir, trench or other device designed to permit all or part of a wastewater flow to be diverted from usual channels or flow. Sometimes refers to a special line which carries the flow around a facility or device that needs maintenance or repair.

BY-PASSING BY-PASSING

The act of causing all or part of a flow to be diverted from its usual channels. In a wastewater treatment plant, overload flows should be by-passed into a holding pond for future treatment.

C

C-ZONED C-ZONED

An area set aside for commercial use.

CABLE STRAIN RELIEF CABLE STRAIN RELIEF

A mesh type of device that grips the cable to prevent any strain on the power cable from reaching the connections to the camera and the light.

CAPILLARY EFFECT (CAP-i-larry) CAPILLARY EFFECT

Also called "wicking effect." The ability of a liquid to rise above an established level to saturate a porous solid.

CATCH BASIN CATCH BASIN

A chamber or well used with storm or combined sewers as a means of removing grit which might otherwise enter and be deposited in sewers. Also see STORM WATER INLET and CURB INLET.

CAULK (KAWK) CAULK

To stop up and make watertight the joints of a pipe by filling the joints with a waterproof compound or material.

CAULKING (KAWK-ing) CAULKING

(1) A waterproof compound or material used to fill a pipe joint.

(2) The act of using a waterproof compound or material to fill a pipe joint.

CAVITATION (CAV-i-TAY-shun) CAVITATION

The formation and collapse of a gas pocket or bubble on the blade of an impeller. The collapse of this gas pocket or bubble drives water into the impeller with a terrific force that can cause pitting on the impeller surface.

CENTRIFUGAL PUMP CENTRIFUGAL PUMP

A pump consisting of an impeller fixed on a rotating shaft and enclosed in a casing, and having an inlet and a discharge connection. As the rotating impeller whirls the liquid around, centrifugal force builds up enough pressure to force the liquid through the discharge outlet.

CESSPOOL CESSPOOL

A lined or partially lined excavation or pit for dumping raw household wastewater for natural decomposition and percolation into the soil.

CFS CFS

Initials stand for "Cubic Feet per Second," a measure of flow rate.

CHECK VALVE CHECK VALVE

A special valve with a hinged disc or flap that opens in the direction of normal flow and is forced shut when flows attempt to go in the reverse or opposite direction of normal flows.

CHEMICAL GROUT CHEMICAL GROUT

Two chemical solutions that form a solid when combined. Solidification time is controlled by the strength of the mixtures used and the temperature.

CHEMICAL GROUTING CHEMICAL GROUTING

Sealing leaks in a pipeline or manhole structure by injecting a chemical grout. In pipelines, the chemicals are injected through a device called a "packer." In operation, the packer is located at the leak point with the use of a television camera. Inflatable boots at either end of the packer isolate the leak point and the grouting chemicals are then forced into the leak under pressure. After allowing time for the grout to set, the packer is deflated and moved to the next location.

CIRCUIT CIRCUIT

The complete path of an electric current, including the generating apparatus or other source; or, a specific segment or section of the complete path.

CIRCUIT BREAKER CIRCUIT BREAKER

A safety device in an electrical circuit that automatically shuts off the circuit when it becomes overloaded. The device can be manually reset.

CHLORINATOR CHLORINATOR

A device used to regulate the transfer of chlorine from a container to flowing wastewater for such purposes as odor control and disinfection.

CLEANING, PIPE CLEANING, PIPE

(See PIPE CLEANING)

CLEANOUT CLEANOUT

An opening (usually covered or capped) in a wastewater collection system used for inserting tools, rods or snakes while cleaning a pipeline or clearing a stoppage.

CLEANOUT, TWO-WAY CLEANOUT, TWO-WAY

A cleanout designed for rodding or working a snake into a pipe in either direction. Two-way cleanouts are often used in building lateral pipes at or near a property line.

CLINICAL LABORATORY CLINICAL LABORATORY

A special medical facility devoted to the identification of diseases and ailments through tests, studies and culture growths. Services of a clinical laboratory might be necessary in the event of an accidental or intentional release or contagious and/or infectious wastes into a collection system.

COAGULATE (co-AGG-you-late) COAGULATE

The use of chemicals that cause very fine particles to clump together into larger particles. This makes it easier to separate the solids from the liquids by settling, skimming, draining or filtering.

COHESIVE (coe-HE-sive) COHESIVE

Tending to stick together.

COLLAPSED PIPE COLLAPSED PIPE

A pipe that has one or more points in its length which have been crushed or partially crushed by exterior pressures or impacts.

COLLECTION MAIN COLLECTION MAIN

A collection pipe to which building laterals are connected.

COLLECTION SYSTEM COLLECTION SYSTEM

A network of pipes, manholes, cleanouts, traps, siphons, lift stations and other structures used to collect all wastewater and wastewater-carried wastes of an area and transport them to a treatment plant or disposal system. The collection system includes land, wastewater lines and appurtenances, pumping stations and general property.

COLLOIDS (KOL-loids) COLLOIDS

Very small, finely divided solids (particles that do not dissolve) that remain dispersed in a liquid for a long time due to their small size and electrical charge.

COMBINED SEWER COMBINED SEWER

A sewer intended to receive both wastewater and storm or surface water.

COMBINED SYSTEM COMBINED SYSTEM

A sewer designed to carry both sanitary wastewaters and storm or surface water runoff.

COMBINED WASTEWATER COMBINED WASTEWATER

A mixture of surface runoff and other wastewater such as domestic of industrial wastewater.

COMMERCIAL CONTRIBUTION COMMERCIAL CONTRIBUTION

Liquid and liquid-carried wastes dumped by commercial establishments into the wastewater collection system. Used in this context, commercial contributions are distinct from domestic and industrial sources of wastewater contributions. Examples of high-yield commercial sources are laundries, restaurants and hotels.

COMMERCIAL TELEVISION QUALITY COMMERCIAL TELEVISION QUALITY

Refers to picture quality about the level of a television picture. Commercial television pictures are considered to have resolutions between 350 and 525 lines. This is higher quality than surveillance quality and lower quality than inspection quality pictures.

COMMINUTOR (com-mih-NEW-ter) COMMINUTOR

A device used to reduce the size of solid chunks in wastewater by shredding (comminuting). The shredding action can be visualized if you imagine many scissors cutting to shreds all the large solids in the wastewater.

COMPACTED BACKFILL COMPACTED BACKFILL

(See BACKFILL COMPACTION)

COMPACTED BEDDING COMPACTED BEDDING

(See BEDDING COMPACTION)

COMPACTION COMPACTION

Tamping or rolling of a material to achieve a surface or density that is able to support predicted loads.

COMPACTION TEST COMPACTION TEST

Any method of determining the weight a compacted material is able to support without damage or displacement. Usually stated in pounds per square foot.

COMPUTED CONTRIBUTION COMPUTED CONTRIBUTION

A liquid or liquid-carried contribution to a collection system that is computed on the basis of expected discharges from all of the sources as opposed to actual measurement or metering. Also see ESTIMATED CONTRIBUTION.

COMPUTED COMMERCIAL CONTRIBUTION COMPUTED COMMERCIAL CONTRIBUTION

That part of a collection system flow computed to originate in the commercial establishments on the basis of expected flows from all commercial sources.

COMPUTED DOMESTIC CONTRIBUTION COMPUTED DOMESTIC CONTRIBUTION

That part of a collection system flow computed to originate in the residential facilities based on the average flow contribution from each person.

COMPUTED FACILITY CONTRIBUTION COMPUTED FACILITY CONTRIBUTION

The computed liquid-waste discharge from a single facility based on the sources of waste flows in the facility.

COMPUTED INDUSTRIAL CONTRIBUTION COMPUTED INDUSTRIAL CONTRIBUTION

The computed liquid-waste discharge from industrial operations based on the expected discharges from all sources.

COMPUTED PER CAPITA CONTRIBUTION COMPUTED PER CAPITA CONTRIBUTION

The computed wastewater contribution from a domestic area, based on the population of the area. In the United States, the daily average wastewater contribution is considered to be 100 gallons per capita per day (100 gpcd).

COMPUTED TOTAL CONTRIBUTION COMPUTED TOTAL CONTRIBUTION

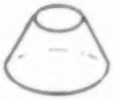
The total anticipated load on a wastewater treatment plant or the total anticipated flow in any collection system area based on the combined computed contributions of all connections to the system.

COMPUTED COLLECTION SYSTEM CONTRIBUTION COMPUTED COLLECTION SYSTEM CONTRIBUTION

That part of a collection system flow computed to be actual domestic and industrial wastewater. Applied to infiltration/inflow research, the computed domestic and industrial wastewater contribution is subtracted from a total flow to determine infiltration/inflow amounts.

CONCENTRIC MANHOLE CONE CONCENTRIC MANHOLE CONE

Cone tapers uniformly from barrel to manhole cover.



CONCRETE CRADLE CONCRETE CRADLE

A device made of concrete that is designed to support sewer pipe.

CONDUCTOR CONDUCTOR

(1) A pipe which carries a liquid load from one point to another point. In a wastewater collection system, a conductor is often a large pipe with no service connections. Also called a CONDUIT, MONITOR, INTERCEPTOR or INTERCONNECTOR.

(2) In plumbing, a line conducting water from the roof to the storm drain or other means of disposal. Also called a DOWNSPOUT.

(3) In electricity, a substance, body, device or wire that readily conducts or carries electrical current.

CONDUIT CONDUIT

Any artificial or natural duct, either open or closed, for conveying fluids from one point to another. An electrical conduit conveys electricity.

CONFINED SPACE* CONFINED SPACE

A space defined by the concurrent existence of the following conditions:

A. Existing ventilation is insufficient to remove dangerous air contamination and/or oxygen deficiency which may exist or develop, and

B. Ready access or egress (getting out) for the removal of a suddenly disabled employee (operator) is difficult due to the location and/or size of the opening(s).

Also see definitions of DANGEROUS AIR CONTAMINATION and OXYGEN DEFICIENCY.

CONTAMINATION CONTAMINATION

Introduction into water of any microorganisms, chemicals, wastes, or wastewater in a concentration that makes the water unfit for its intended use.

CONTRIBUTION CONTRIBUTION

Waters, wastewaters or liquid-carried wastes entering a wastewater collection system.

COULOMB (COO-lahm) COULOMB

A measurement of the amount of electrical charge conveyed by an electric current of one ampere in one second. One coulomb equals about 6.25×10^{18} electrons (6,250,000,000,000,000,000 electrons).

COUPLING COUPLING

(1) A threaded sleeve used to connect two pipes.

(2) A device used to connect two adjacent parts, such as a pipe coupling, hose coupling or drive coupling.

CROSS BRACES CROSS BRACES

Shoring members placed across a trench to hold other horizontal and vertical members in place.

CROSS CONNECTION CROSS CONNECTION

(1) A connection between a storm drain system and a sanitary collection system.

(2) Less frequently used to mean a connection between two sections of a collection system to handle anticipated overloads of one system.

(3) A connection between drinking (potable) water and an unsafe water supply.

CURB INLET CURB INLET

A chamber or well built at the curbline of a street to admit gutter flow to the storm water drainage system. Also see STORM WATER INLET and CATCH BASIN.

CURRENT CURRENT

A movement or flow of electricity.

Water flowing in a pipe is measured in gallons per second past a certain point, not by the number of water molecules going past a point. Electric current is measured by the number of coulombs per second flowing past a certain point in a conductor. A coulomb is equal to about 6.25×10^{18} electrons (6,250,000,000,000,000,000 electrons). A flow of one coulomb per second is called 1 ampere, the unit of the rate of flow of current.

D

DANGEROUS AIR CONTAMINATION DANGEROUS AIR CONTAMINATION

An atmosphere presenting a threat of causing death, injury, acute illness, or disablement due to the presence of flammable and/or explosive, toxic or otherwise injurious or incapacitating substances.

A. Dangerous air contamination due to the flammability of a gas or vapor is defined as an atmosphere containing the gas or vapor at a concentration greater than 20 percent of its lower explosive (lower flammable) limit.

B. Dangerous air contamination due to a combustible particulate is defined as a concentration greater than 20 percent of the minimum explosive concentration of the particulate.

C. Dangerous air contamination due to the toxicity of a substance is defined as the atmospheric concentration immediately hazardous to life or health.

***CONFINED SPACES, General Industry Safety Orders, Article 108, Title 8, California Administrative Code, Cal/OSHA Consultation Service, Sacramento, California, October 1980.*

DATA-VIEW **DATA-VIEW**

A high-speed reporting and recording system used with closed circuit pipeline television equipment. Data-view provides digital indexing of date, job number, footages and air test pressures in the television picture itself. Where video tape recordings of television pipe inspections or pipe sealing activities are made, data-view reports are automatically recorded on the taped pictures.

DEADEND MANHOLE **DEADEND MANHOLE**

A manhole located at the upstream end of a sewer and having no inlet pipe. Also called a TERMINAL MANHOLE.

DEBRIS (de-BREE) **DEBRIS**

Any material in wastewater found floating, suspended or moving along the bottom of a sewer. This material may cause stoppages by getting hung up on roots or settling out in a sewer. Debris includes grit, paper, plastic, rubber, silt, and all materials except liquids.

DEBRIS, INFILTRATED **DEBRIS, INFILTRATED**

(See INFILTRATED DEBRIS)

DECOMPOSED PIPE **DECOMPOSED PIPE**

Pipe which has been destroyed or portions of pipe weakened by chemical actions.

DECOMPOSITION, DECAY **DECOMPOSITION, DECAY**

Processes that convert unstable materials into more stable forms by chemical or biological action. Waste treatment encourages decay in a controlled situation so that material may be disposed of in a stable form. When organic matter decays under anaerobic conditions (putrefaction), undesirable odors are produced. The aerobic processes in common use for wastewater treatment produce much less objectionable odors.

DEFECT **DEFECT**

A point where a pipe or system structure has been damaged or has a fault.

DEFECT, SURFACED **DEFECT, SURFACED**

(see SURFACED DEFECT)

DEFLECTED **DEFLECTED**

(1) Pipe which has been forced out of round by external pressures. This happens mainly to fiber and plastic pipes where backfill compaction has resulted in unequal pressures on all sides of the pipe.

(2) Pipe whose direction has been changed either to the left, right, up, or down.

DEGRADATION (de-grah-DAY-shun) **DEGRADATION**

The conversion or breakdown of a substance to simpler compounds. For example, the degradation of organic matter to carbon dioxide and water.

DESTROYED PIPE **DESTROYED PIPE**

Pipe which has been damaged, decomposed, deflected, crushed or collapsed to a point that it must be replaced.

DETENTION **DETENTION**

The delay or holding of the flow of water and water-carried wastes in a pipe system. This can be caused by a restriction in the pipe, a stoppage or a dip. Detention also means the time water is held or stored in a basin or a wet well. Sometimes called RETENTION.

DETRITUS (de-TRY-tus) **DETRITUS**

The heavy, coarse mixture of grit and organic material carried by wastewater. Also called GRIT.

DEWATER **DEWATER**

To drain or remove water from an enclosure. A structure may be dewatered so that it can be inspected or repaired. Dewater also means draining or removing water from sludge to increase the solids concentration.

DIP **DIP**

A point in a sewer pipe where a drain grade defect results in a puddle of standing water when there is no flow. If the grade defect is severe enough to cause the standing water to fill the pipe at any point (preventing passage of air through the pipe), it is called a "trap dip," "full dip" or "filled dip."

DIRECT CURRENT (D.C.) **DIRECT CURRENT (D.C.)**

Electrical current flowing in one direction only and essentially free from pulsation.

DISCHARGE HEAD DISCHARGE HEAD

The pressure (in feet or pounds per square inch (psi)) on the discharge side of a pump. The pressure can be measured from the center line of the pump to the hydraulic grade line of the water in the discharge pipe.

DISINFECTION (DIS-in-feck-shun) DISINFECTION

The process designed to kill most microorganisms in wastewater, including essentially all pathogenic (disease-causing) bacteria. There are several ways to disinfect, with chlorine being the most frequently used in water and wastewater treatment plants.

DISPLACED PIPE DISPLACED PIPE

A run or section of sewer pipe that has been pushed out of alignment by external forces.

DISTURBED SOIL DISTURBED SOIL

Soil which has been changed from its natural condition by excavation or other means.

DIVERSION CHAMBER DIVERSION CHAMBER

A chamber or box which contains a device for diverting or drawing off all or part of a flow or for discharging portions of the total flow to various outlets. Also called a REGULATOR.

DOMESTIC DOMESTIC

Residential living facilities. A domestic area will be predominantly residential in occupancy and is sometimes referred to as a "bedroom area" or "bedroom community."

DOMESTIC CONTRIBUTION DOMESTIC CONTRIBUTION

Wastes originating in a residential facility or dwelling. In this use, it means the type and quantity of wastes are different from commercial and industrial or agricultural wastes.

DOMESTIC SERVICE DOMESTIC SERVICE

A connection to a sewer system for hookup of a residential-type building.

DOWNSPOUT DOWNSPOUT

In plumbing, the water conductor from the roof gutters or roof catchment to the storm drain or other means of disposal. Also called a "roof leader", or "roof drain."

DOWNSTREAM DOWNSTREAM

The direction of the flow of water. In the lower part of a sewer or collection system or in that direction.

DRAGLINE DRAGLINE

A machine that drags a bucket down the intended line of a trench to dig or excavate the trench. Also used to dig holes and move soil or aggregate.

DROP JOINT DROP JOINT

A sewer pipe joint where one part has dropped out of alignment. Also called a VERTICAL OFFSET.

DROP MANHOLE DROP MANHOLE

(1) A shaft in which wastewater is allowed to fall or drop from a higher level to the bottom (invert) of the manhole.

(2) In some manholes with drop lines, a connection is made to the line outside of the manhole and the flow is conducted down to the invert or trough of the manhole through this connection.

DRY PIT DRY PIT

(See DRY WELL)

DRY WELL DRY WELL

A dry room or compartment in a lift station, near or below the water level, where the pumps are located.

DWELLING DWELLING

A structure for residential occupancy.

DYNAMIC HEAD DYNAMIC HEAD

When a pump is operating, the vertical distance (in feet) from a point to the energy grade lines. Also see TOTAL DYNAMIC HEAD, STATIC HEAD, and ENERGY GRADE LINE.

E

EARTH SHIFT EARTH SHIFT

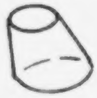
The movement or dislocation of underground soil or structure. Earth shift is usually caused by external forces such as surface loads, slides, stresses or nearby construction, water movements or seismic forces.

EASEMENT EASEMENT

Legal right to use the property of others for a specific purpose. For example, a utility company may have a five-foot easement along the east property line of a home. This gives the utility the legal right to install and maintain a sewer line within the easement.

ECCENTRIC MANHOLE CONE ECCENTRIC MANHOLE CONE

Cone tapers nonuniformly from barrel to manhole cover with one side usually vertical.



EFFLUENT (EF-lou-ent) EFFLUENT

Wastewater or other liquid — raw, partially or completely treated — flowing *FROM* a basin, treatment process, or treatment plant.

ELBOW ELBOW

A pipe fitting that connects two pipes at an angle. The angle is always 90 degrees unless another angle is stated. Also called an ELL.

ELECTROLYTE SOLUTION (e-LECK-tro-light) ELECTROLYTE SOLUTION

A special solution that is capable of conducting electricity.

ELECTROMOTIVE FORCE (E.M.F.) ELECTROMOTIVE FORCE (E.M.F.)

The electrical pressure available to cause a flow of current (amperage) when an electrical circuit is closed. See VOLTAGE.

ELECTRON ELECTRON

A very small, negatively-charged particle which is practically weightless. According to the electron theory, all electrical and electronic effects are caused either by the movement of electrons from place to place or because there is an excess or lack of electrons at a particular place.

EMULSION (e-MULL-shun) EMULSION

A liquid mixture of two or more liquid substances not normally dissolved in one another; one liquid is held in suspension in the other.

ENCLOSED SPACE ENCLOSED SPACE

(See CONFINED SPACE)

ENERGY GRADE LINE (E.G.L.) ENERGY GRADE LINE (E.G.L.)

A line that represents the elevation of energy head of water flowing in a pipe, conduit or channel. The line is drawn above the hydraulic grade line a distance equal to the velocity head of the water flowing at each section or point along the pipe or channel.

ESTIMATED CONTRIBUTION ESTIMATED CONTRIBUTION

A contribution to a collection system that is estimated rather than computed. The distinction between computed and estimated in such cases is difficult to specify or define. Also see COMPUTED CONTRIBUTION.

ESTIMATED FLOW ESTIMATED FLOW

A rough guess of the amount of flow in a collection system. When greater accuracy is needed, flow could be computed using average or typical flow quantities. Even greater accuracy would result from metering or otherwise measuring the actual flow.

EXFILTRATION (EX-fill-TRAY-shun) EXFILTRATION

Liquid wastes and liquid-carried wastes which unintentionally leak out of a sewer pipe system and into the environment.

EXTRADOS EXTRADOS

The upper outside curve of a sewer pipe or conduit.

EXTREMELY HAZARDOUS WASTE EXTREMELY HAZARDOUS WASTE

Any hazardous waste or mixture of hazardous wastes which, if any human exposure should occur, may likely result in death, disabling personal injury or illness during, or as approximate result of, any disposal of such waste or mixture of wastes because of its quantity, concentration, or chemical characteristics. (Subsection 23115 of Article 2, Chapter 6.5, Division 20 of the California Health and Safety Code.) Also see HAZARDOUS WASTE.

F

FAIR LEAD PULLEY (fair-LEE-d-pully) FAIR LEAD PULLEY

A pulley that is placed in a manhole to guide a TV camera, electric cables, and the pull cable into the sewer when inspecting pipelines.

FAULT FAULT

(1) A fracture in the earth's crust that leaves land on one side of the crack out of alignment with the other side. Faults are generally a result of earth shifts and earthquakes.

(2) (See DEFECT)

FILLED DIP FILLED DIP

(See DIP)

FLAP GATE FLAP GATE

A hinged gate that is mounted at the top of a pipe or channel to allow flow in only one direction. Flow in the wrong direction closes the gate. Also see Check Valve and Tide Gate.

FLOAT (CONTROL) FLOAT (CONTROL)

A device used to measure the elevation of the surface of water. The float rests on the surface of the water and rises or falls with it. The elevation of the water surface is measured by a rod, chain, rope or tape attached to the float.

FLOAT LINE FLOAT LINE

A length of rope or heavy twine attached to a float, plastic jug or parachute to be carried by the flow in a sewer from one manhole to the next. This is called "stringing the line" and is used for pulling through winch cables, such as for bucket machine work or closed-circuit television work.

FLOTATION FLOTATION

(1) The stress or forces on a pipeline or manhole structure located below a water table which tend to lift or float the pipeline or manhole structure.

(2) The process of raising suspended matter to the surface of the liquid in a tank where it forms a scum layer that can be removed by skimming. The suspended matter is raised by aeration, the evolution of gas, the use of chemicals, electrolysis, heat or bacterial decomposition.

FLOTSAM (FLOAT-sam) FLOTSAM

(See SURFACE SOLIDS)

FLOW FLOW

The continuous movement of a liquid from one place to another.

FLOW LINE FLOW LINE

(1) The top of the wetted line, the water surface or the hydraulic grade line of water flowing in an open channel or partially full conduit.

(2) The lowest point of the channel inside a pipe or manhole. See INVERT. *NOTE:* (2) is an improper definition, although used by some contractors.

FLOW RECORDING FLOW RECORDING

A record of a flow measurement past any selected point. Usually consists of time, velocity and amount (in gallons) with maximum and minimum rates as well as the total amount over a given time period.

FLUME FLUME

An open conduit of wood, masonry, metal, or plastic constructed on a grade and sometimes elevated. Sometimes called an "aqueduct" or "channel."

FLUME, PARSHALL FLUME, PARSHALL

(See PARSHALL FLUME)

FLUSHER BRANCH FLUSHER BRANCH

A line built specifically to allow the introduction of large quantities of water to the collection system so the lines can be "flushed out" with water. Also installed to provide access for equipment to clear stoppages in a sewer.

FLUSHING FLUSHING

The removing of deposits of material which have lodged in sewers because of inadequate velocity of flows. Water is discharged into the sewers at such rates that the larger flow and higher velocities are sufficient to remove the material.

FORCE MAIN FORCE MAIN

A pipe that carries wastewater under pressure from the discharge side of a pump to a point of gravity flow downstream.

FRIABILITY (FRY-ability) FRIABILITY

The ability of a soil or substance to crumble under moderate or light pressure.

FRICTION LOSS FRICTION LOSS

The head lost by water flowing in a stream or conduit as the result of the disturbances set up by the contact between the moving water and its containing conduit and by intermolecular friction.

FULL DIP FULL DIP

(See DIP)

FUSE FUSE

A protective device having a strip or wire of fusible metal which, when placed in a circuit, will melt and break the electrical circuit if heated too much. High temperatures will develop in the fuse when a current flows through the fuse in excess of that which the circuit will carry safely.

G

GAGE GAGE

A device for checking or measuring a particular dimension of something, using specific standardized units. For example, a gage might measure the elevation of a water surface, the velocity of flowing water, the pressure of water, the amount or intensity of precipitation, and the depth of snowfall. Gages also are used to determine the location or position of equipment during installation and after operation.

GAS (SEWER) GAS (SEWER)

(See SEWER GAS)

GEL OR GELL GEL OR GELL

(1) A term sometimes applied to chemical grout. See CHEMICAL GROUT.

(2) A form of matter in a colloidal state that does not dissolve, but remains suspended in a solvent. It does not precipitate out of the solvent without the intervention of heat or of an electrolyte.

GEOLOGY GEOLOGY

The science that deals with the origin, history and structures of the earth, as recorded in the rocks, together with the forces and processes now operating to modify rocks.

GEOLOGY, SUBSOIL GEOLOGY, SUBSOIL

(See SUBSOIL GEOLOGY)

GEOLOGY, SUBSTRUCTURE GEOLOGY, SUBSTRUCTURE

(See SUBSOIL GEOLOGY)

GPCD GPCD

Initials standing for "Gallons Per Capita per Day."

GPD GPD

Initials standing for "Gallons Per Day."

GPM GPM

Initials standing for "Gallons Per Minute."

GPY GPY

Initials standing for "Gallons Per Year."

GRADE GRADE

(1) The elevation of the invert of the bottom of a pipeline, canal, culvert, sewer, or similar conduit.

(2) The inclination or slope of a sewer, conduit, stream channel, or natural ground surface, usually expressed in terms of the ratio or percentage of number of units of vertical rise or fall per unit of horizontal distance. A 0.5 percent grade would be a drop of one-half foot per hundred feet of pipe.

GRANULAR GRANULAR

Any substance that appears to consist of separate granules or grains. Examples are sand and gravel.

GRAVITY GRAVITY

The attraction of the earth to any substance — solid, liquid or gas.

GRAVITY FLOW GRAVITY FLOW

Water or wastewater flowing from a higher elevation to a lower elevation due to the force of gravity. The water does not flow due to energy provided by a pump. Wherever possible, wastewater collection systems are designed to use the force of gravity to convey waste liquids and solids.

GRAVITY, SPECIFIC GRAVITY, SPECIFIC

(See SPECIFIC GRAVITY)

GREASE GREASE

In a collection system, grease is considered to be the residues of fats, detergents, waxes, free fatty acids, calcium and magnesium soaps, mineral oils, and certain other nonfatty materials which tend to separate from water and coagulate as floatables or scums.

GREASE BUILDUP GREASE BUILDUP

Any point in a collection system where coagulated and solidified greases accumulate and build up. Many varieties of grease have high adhesive characteristics and collect other solids, forming restrictions and stoppages in collection systems.

GREASE TRAP GREASE TRAP

A receptacle designed to collect and retain grease and fatty substances usually found in kitchens or from similar wastes. It is installed in the drainage system between the kitchen or other point or production of the waste and the building wastewater collection line.

GRIT GRIT

The heavy mineral material present in wastewater such as sand, coffee grounds, eggshells, gravel and cinders. Grit tends to settle out at flow velocities below 2 ft/sec and accumulate in the invert or bottoms of the pipelines.

GRIT CATCHER GRIT CATCHER

A chamber usually placed at the upper end of a depressed collection line or at other points on combined or storm collection lines where wear from grit is possible; the chamber is sized and shaped to reduce the velocity of flow through it and thus permit the settling out of grit. Also called "sand catcher." See GRIT CHAMBER and SAND TRAP.

GRIT CHAMBER GRIT CHAMBER

A detention chamber or an enlargement of a collection line designed to reduce the velocity of flow of the liquid to permit the separation of mineral from organic solids by differential sedimentation.

GRIT CHANNEL GRIT CHANNEL

(1) An enlargement in a collection line where grit can easily settle out of the flow.

(2) The waterway of a grit chamber.

GRIT COLLECTOR GRIT COLLECTOR

A device placed in a grit chamber to convey deposited grit to a point of collection.

GRIT COMPARTMENT GRIT COMPARTMENT

The portion of the grit chamber in which grit is collected and stored before removal.

GRIT SEPARATOR GRIT SEPARATOR

A device located at the inlet to a treatment plant for the accumulation and removal of grit.

GRIT TRAP GRIT TRAP

(1) A permanent structure built into a manhole (or other convenient location in a collection system) for the accumulation and easy removal of grit.

(2) (See SAND TRAP)

GROUNDWATER GROUNDWATER

Subsurface water in the saturation zone from which wells and springs are fed. In a strict sense the term applies only to water below the water table. Also called "phreatic water" and "plerotic water."

GROUNDWATER DEPTH GROUNDWATER DEPTH

The distance of the groundwater table below the surface at any selected location.

GROUNDWATER ELEVATION GROUNDWATER ELEVATION

The elevation of the groundwater table above mean sea level at any selected location.

GROUNDWATER TABLE GROUNDWATER TABLE

The average depth or elevation of the groundwater over a selected area.

GROUNDWATER TABLE, ARTIFICIAL GROUNDWATER TABLE, ARTIFICIAL

(See ARTIFICIAL GROUNDWATER TABLE)

GROUNDWATER TABLE, SEASONAL GROUNDWATER TABLE, SEASONAL

(See SEASONAL GROUNDWATER TABLE)

GROUNDWATER TABLE, TEMPORARY GROUNDWATER TABLE, TEMPORARY

(See TEMPORARY GROUNDWATER TABLE)

GROUT GROUT

A substance in a paste or liquid form which solidifies after placement or treatment. Used to fill spaces, holes or voids in other materials.

GROUT, CHEMICAL GROUT, CHEMICAL

(See CHEMICAL GROUT)

GROUTING, PRESSURE GROUTING, PRESSURE

(See CHEMICAL GROUTING)

GUNITE GUNITE

A mixture of sand and cement applied pneumatically that forms a high density, resistance concrete.

H

HAIRLINE CRACK HAIRLINE CRACK

A stress crack in a pipe that looks like a piece of hair.

HAND ROD HAND ROD

A sewer rod that can be inserted manually (by hand) into a sewer to clear a stoppage or to prevent a stoppage from developing.

HANDHOLE TRAP HANDHOLE TRAP

A device made of pipe fittings used to prevent sewer gases escaping from the branch or lateral sewer from entering a building sewer.

HAZARDOUS WASTE HAZARDOUS WASTE

Any waste material or mixture of wastes which is toxic, corrosive, flammable, an irritant, a strong sensitizer which generates pressure through decomposition, heat or other means, if such a waste or mixture of wastes may cause substantial personal injury, serious illness or harm to wildlife, during, or as approximate result of any disposal of such wastes or mixture of wastes. The terms "toxic," "corrosive," "flammable," "irritant," and "strong sensitizer" shall be given the same meanings as given by the California Hazardous Substance Act (Chapter 13 (commencing with Section 28740) of Division 21) (Subsection 23117 of Article 2, Chapter 6.5, Division 20 of the California Health and Safety Code). Also see EXTREMELY HAZARDOUS WASTE.

HEAD HEAD

A term used to describe the height or energy of water above a point. A head of water may be measured in either height (feet) or pressure (pounds per square inch (psi)). Also see DISCHARGE HEAD, DYNAMIC HEAD, STATIC HEAD, SUCTION HEAD, SUCTION LIFT, and VELOCITY HEAD.

HERTZ (HURTS) HERTZ

The number of complete electromagnetic cycles or waves in one second of an electrical or electronic circuit. Also called the frequency of the current. Abbreviated Hz.

HIGH VELOCITY CLEANER HIGH VELOCITY CLEANER

A machine designed to remove grease and debris from the smaller diameter sewer pipes with jets of high velocity water. Also called a "jet cleaner," "jet rodder," "hydraulic cleaner," or "high pressure cleaner."

HOUSE CONNECTION HOUSE CONNECTION

(See BUILDING SEWER)

HOUSE SERVICE HOUSE SERVICE

(See BUILDING SERVICE)

HOUSE SEWER HOUSE SEWER

(See BUILDING SEWER)

HUB HUB

In pipe fitting, the enlarged female end of a pipe into which the male end fits. Also called a BELL.

HYDRAULIC BLOCK HYDRAULIC BLOCK

The movement of water in such a way that the flow of water from one direction blocks or hinders the flow of water from another direction.

HYDRAULIC CLEANER HYDRAULIC CLEANER

(See HIGH VELOCITY CLEANER)

HYDRAULIC CLEANING HYDRAULIC CLEANING

Cleaning pipe with water under enough pressure to produce high water velocities.

(1) Using a high velocity cleaner.

(2) Using a ball, kite or similar sewer-cleaning device.

(3) Using a scooter.

(4) Flushing.

HYDRAULIC GRADE LINE (H.G.L.) HYDRAULIC GRADE LINE (H.G.L.)

The surface or profile of water flowing in an open channel or a pipe flowing partially full. If a pipe is under pressure, the hydraulic grade line is at the level water would rise to in a small tube connected to the pipe. To reduce the release of odors from sewers, the water surface or hydraulic grade line should be kept as smooth as possible.

HYDRAULIC POPULATION EQUIVALENT HYDRAULIC POPULATION EQUIVALENT

A flow of 100 gallons per day is the hydraulic or flow equivalent to the contribution or flow from one person. Population equivalent = 100 gpcd or gallons per capita per day.

HYDROGEN SULFIDE GAS (H_2S) HYDROGE SULFIDE GAS (H_2S)

Hydrogen sulfide is a gas with a rotten egg odor. This gas is produced under anaerobic conditions. Hydrogen sulfide is particularly dangerous because it dulls your sense of smell so that you don't notice it after you have been around it for a while and because the odor is not noticeable in high concentrations. The gas is very poisonous to your respiratory system, explosive and flammable.

HYDROLOGY HYDROLOGY

The applied science concerned with the waters of the earth in all their states — their occurrence, distribution, and circulation through the unending hydrologic cycle of precipitation, consequent runoff, stream flow, infiltration, and storage, eventual evaporation, and reprecipitation. Hydrology is concerned with the physical, chemical, and physiological reactions of water with the rest of the earth and its relation to the life of the earth.

HYDROPHILIC HYDROPHILIC

Water loving.

I

IMPELLER IMPELLER

A rotating set of vanes in a pump designed to pump or lift water.

IMPORTED BACKFILL IMPORTED BACKFILL

Material used for backfilling a trench or excavation which was not the original material removed during excavation. This is a common practice where tests on the original material show it to have poor compactability or load capacity. Also called BORROW BACKFILL.

INDUSTRIAL TELEVISION EQUIPMENT INDUSTRIAL TELEVISION EQUIPMENT

(See INSPECTION TELEVISION CAMERA)

INDUSTRIAL WASTEWATER INDUSTRIAL WASTEWATER

Liquid wastes originating from industrial processing. Because industries have peculiar liquid waste characteristics requiring special consideration, these sources are usually handled and treated separately.

INFILTRATED DEBRIS INFILTRATED DEBRIS

Sand, silt, gravel and rocks carried or washed into a collection system by infiltration water flows.

INFILTRATION (IN-fill-TRAY-shun) INFILTRATION

The water entering a sewer pipe, including service connections, from the ground. Defective pipes, pipe joints, connections or manhole walls are a few of the common locations where infiltration may occur.

INFILTRATION/INFLOW INFILTRATION/INFLOW

The total quantity of water from both infiltration and inflow without distinguishing the source.

INFILTRATION HEAD INFILTRATION HEAD

The distance from a point of infiltration leaking into a collection system to the water table elevation. This is the pressure of the water being forced through the leak in the collection system.

INFILTRATION PRESSURE INFILTRATION PRESSURE

(See INFILTRATION HEAD)

INFILTRATION, TEMPORARY INFILTRATION, TEMPORARY

(See TEMPORARY INFILTRATION)

INFLATABLE PIPE STOPPER INFLATABLE PIPE STOPPER

An inflatable ball or bag used to form a plug to stop flows in a sewer pipe.

INFLOW INFLOW

The water discharged into a sewer system and service connections from such sources as, but not limited to, roof leaders, cellar, yard and area drains, foundation drains, cooling water discharges, drains from springs and swampy areas, around manhole covers or through holes in the covers, cross connections from storm and combined sewer systems, catch basins, storm waters, surface runoff, street wash waters or drainage. See INTERNAL FLOW.

INFLUENT INFLUENT

Wastewater or other liquid — raw or partially treated — flowing *INTO* a reservoir, basin, treatment process, or treatment plant.

INLET INLET

(1) A surface connection to a drain pipe.

(2) A chamber for collecting storm water with no well below the outlet pipe for collecting grit. Often connected to a CATCH BASIN or a "basin manhole" ("cleanout manhole") with a grit chamber.

INORGANIC WASTE INORGANIC WASTE

Waste material such as sand, salt, iron, calcium, and other mineral materials which are only slightly affected by the action of organisms. Inorganic wastes are chemical substances of mineral origin; whereas organic wastes are chemical substances usually of animal or vegetable origin.

INSPECTION TELEVISION EQUIPMENT INSPECTION TELEVISION EQUIPMENT

Television equipment that is superior to standard commercial quality, providing 600 to 650 lines of resolution, and designed for industrial inspection applications. Also known as INDUSTRIAL TELEVISION EQUIPMENT.

INTERCEPTING SEWER INTERCEPTING SEWER

A sewer that receives flow from a number of other large sewers or outlets and conducts the waters to a point for treatment or disposal. Often called an "interceptor."

INTERCONNECTOR INTERCONNECTOR

A sewer installed to connect two separate sewers. If one sewer becomes blocked, wastewater can back up and flow through the interconnector to the other sewer.

INTERNAL INFLOW INTERNAL INFLOW

Non-sanitary or industrial wastewaters generated inside of a domestic, commercial or industrial facility and being discharged into the sewer system. Examples are cooling tower waters, basement sump pump discharge waters, continuous-flow drinking fountains, and defective or leaking plumbing fixtures.

INTRADOS INTRADOS

The upper inside curve or surface of a sewer pipe or conduit.

INVERT INVERT

The lowest point of the channel inside a pipe or manhole. See FLOW LINE.

INVERTED SIPHON INVERTED SIPHON

A pressure pipeline used to carry wastewater flowing in a gravity collection system under a depression such as a valley or roadway or under a structure such as a building. Also called a DEPRESSED SEWER.

J

JET CLEANER JET CLEANER

(See HIGH VELOCITY CLEANER)

JET RODDER JET RODDER

(See HIGH VELOCITY CLEANER)

JETSAM (JET-sam) JETSAM

Debris entering a collection system which is heavier than water. Also see GRIT.

JOINT JOINT

A connection between two lengths of pipe, made either with or without the use of another part.

K

KEY MANHOLE KEY MANHOLE

In collection system evaluation, a key manhole is one from which reliable or specific data can be obtained.

KITE KITE

A device for hydraulically cleaning sewer lines. Resembling an airport wind sock and constructed of canvas-type material, the kite increases the velocity of a flow at its outlet to wash debris ahead of it.

L

LAMP HOLE LAMP HOLE

A small vertical pipe or shaft extending from the surface of the ground to a sewer. A light (or lamp) may be lowered down the pipe for the purpose of inspecting the sewer. Rarely constructed today.

LAMPING LAMPING

Using reflected sunlight or a powerful light beam to inspect a sewer between two adjacent manholes. The light is directed down the pipe from one manhole. If it can be seen from the next manhole, it indicates that the line is open and straight.

LATERAL LATERAL

(See BUILDING LATERAL)

LATERAL BREAK LATERAL BREAK

A break in a lateral pipe somewhere between the sewer main and the building connection.

LATERAL CLEANOUT LATERAL CLEANOUT

A capped opening in a building lateral, usually located on the property line, through which the pipelines can be cleaned.

LATERAL CONNECTION LATERAL CONNECTION

(See BUILDING SERVICE)

LATERAL SEWER LATERAL SEWER

A sewer that discharges into a branch or other sewer and has no other common sewer tributary to it. Sometimes called a "street sewer" because it collects wastewater from individual homes.

LEAD (LEE-d) LEAD

A wire or conductor that can carry electrical current.

LIFT STATION LIFT STATION

A wastewater pumping station that lifts the wastewater to a higher elevation when continuing the sewer at reasonable slopes would involve excessive depths of trench. Also, an installation of pumps that raise wastewater from areas too low to drain into available sewers. These stations may be equipped with air-operated ejectors or centrifugal pumps. Sometimes called a PUMP STATION, but this term is usually reserved for a similar type of facility that is discharging into a long FORCE MAIN, while a lift station has a discharge line or force main only up to the downstream gravity sewer. Throughout this manual when we refer to lift stations, we intend to include pump stations.

LINER LINER

(See PIPE LINER)

LIQUID VEHICLE LIQUID VEHICLE

Water in a collection system that is used to carry non-liquid wastes. The standard toilet provides around seven gallons of water per flush as a vehicle to carry wastes through the pipe system.

LIQUOR LIQUOR

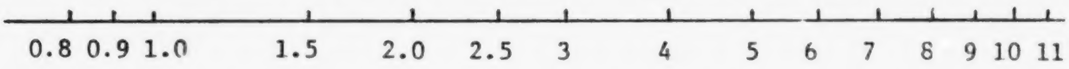
Water, wastewater, or any combination; commonly used to mean the liquid portion when other wastes are also present.

LOGARITHM (LOG-a-rith-m) LOGARITHM

The exponent that indicates the power to which a number must be raised to produce a given number. For example: if $B^2 = N$, then 2 is the logarithm of N (to the base B), or $10^2 = 100$ and $\log_{10} 100 = 2$.

LOGARITHMIC SCALE (LOG-a-rith-mick) LOGARITHMIC SCALE

A scale on which actual distances from the origin are proportional to the logarithms of the corresponding scale numbers rather than to the numbers themselves. A logarithmic scale has the numbers getting bigger as the distances between the numbers decreases.



LONGITUDINAL CRACK (LAWN-ji-TWO-da-null) LONGITUDINAL CRACK

A crack in a pipe or pipe section that runs lengthwise along the pipe.

LUBRIFLUSHING (LOOB-rah-FLUSH-ing) LUBRIFLUSHING

A method of lubricating bearings with grease. Remove the relief plug and apply the proper lubricant to the bearing at the lubrication fitting. Run the pump to expel excess lubricant.

M

M-ZONED M-ZONED

An area set aside for manufacturing and industry.

MAIN LINE MAIN LINE

Branch or lateral sewers that collect wastewater from building sewers and service lines.

MAIN SEWER MAIN SEWER

A sewer line that receives wastewater from many tributary branches and sewer lines and serves as an outlet for a large territory or used to feed an intercepting sewer.

MANDREL (MAN-drill) MANDREL

(1) A special tool used to push bearings in or to pull sleeves out.

(2) A gage used to measure for excessive deflection in a flexible conduit.

MANHOLE MANHOLE

An opening in a sewer provided for the purpose of permitting operators or equipment to enter or leave a sewer. Sometimes called an "access hole."

MANHOLE BEDDING MANHOLE BEDDING

The prepared and compacted base on which a manhole is constructed.

MANHOLE DEPTH MANHOLE DEPTH

The measurement from the top of the manhole opening to the invert or lowest point of the trough at the bottom of the manhole.

MANHOLE, DROP MANHOLE, DROP

(See DROP MANHOLE)

MANHOLE ELEVATION MANHOLE ELEVATION

The height (elevation) of the invert or lowest point in the bottom of a manhole above mean sea level.

MANHOLE FLOW MANHOLE FLOW

(1) The depth or amount of wastewater flow in a manhole as observed at any selected time.

(2) The total or the average flow through a manhole in gallons in any selected time interval.

MANHOLE FRAME MANHOLE FRAME

A metal ring or frame with a ledge to accommodate the manhole lid; located at the surface of the ground or street. Also called a MANHOLE RING.

MANHOLE INFILTRATION MANHOLE INFILTRATION

Groundwaters seeping or leaking into a manhole structure.

MANHOLE INFLOW MANHOLE INFLOW

Surface waters flowing into a manhole, usually through the vent holes in the manhole lid.

MANHOLE INVERT MANHOLE INVERT

The lowest point in a trough or flow channel in the bottom of a manhole.

MANHOLE, KEY MANHOLE, KEY

(See KEY MANHOLE)

MANHOLE LID MANHOLE LID

The heavy cast iron or forged steel cover of a manhole. The lid may or may not have vent holes.

MANHOLE LID DUST PAN MANHOLE LID DUST PAN

A sheet metal or cast iron pan located under a manhole lid. This pan serves to catch and hold pebbles and other debris falling through vent holes, preventing them from getting into the pipe system.

MANHOLE RING MANHOLE RING

A metal frame or ring with a ledge to accommodate the lid and located at the surface of the ground or street. Also called a MANHOLE FRAME.

MANHOLE SEALING MANHOLE SEALING

The process of sealing up infiltration leaks in a manhole by injecting chemical grout.

MANHOLE, SURCHARGED MANHOLE, SURCHARGED

(See SURCHARGED MANHOLE)

MANHOLE TOOLS MANHOLE TOOLS

(1) Special tools having conveniently short handles for working inside manholes.

(2) Special long-handled or extendable tools for removal of debris and other objects from manholes without requiring a person to enter the manhole.

MANHOLE TROUGH MANHOLE TROUGH

The channel in the bottom of a manhole for the flow of the wastewater from manhole inlet to outlet.

MANHOLE VENTS MANHOLE VENTS

5

One or a series of one-inch diameter holes through a manhole lid for purposes of venting off dangerous gases found in sewers.

MANNING'S FORMULA MANNING'S FORMULA

A mathematical formula for calculating wastewater flows in sewers.

$$Q = \frac{1.49}{n} A R^{2/3} S^{1/2}$$

Q means flow in cubic feet per second (cfs).
N means the Manning pipe or channel roughness factor.
A means the cross-sectional area of the flow in square feet (sq ft).
R means the hydraulic radius in feet (ft) where R equals A/P. P is the wetted perimeter of the channel or pipe in feet.
S means the slope of the channel or energy grade line in feet per foot (ft/ft)

MANNING'S TABLES MANNING'S TABLES

A set of tables for finding wastewater flows in sewers.

MANOMETER (man-NOM-muh-ter) MANOMETER

Usually a glass tube filled with a liquid and used to measure the difference in pressure across a flow-measuring device such as an orifice or a venturi meter.

MEASURED FLOW MEASURED FLOW

A flow which has been physically measured. See GAGE.

MECHANICAL CLEANING MECHANICAL CLEANING

Clearing pipe by using equipment that scrapes, cuts, pulls or pushes the material out of the pipe. Mechanical cleaning devices or machines include bucket machines, power rodders and hand rods.

MECHANICAL PLUG MECHANICAL PLUG

A pipe plug used in sewer systems that is mechanically expanded to create a seal.

MEGGER (from "megohm") MEGGER

An instrument used for checking the insulation resistance on motors, feeders, buss bar systems, grounds, and branch circuit wiring.

METERED METERED

Measured through a meter, as a quantity of water or flow might be measured.

MG MG

Initials for "Million Gallons."

MGD MGD

Initials for "Million Gallons per Day."

mg/*L* mg/*L*

Intials for "Milligrams per Liter." A measure of the concentration by weight of a substance per unit volume in water or wastewater. In reporting the results of water and wastewater analysis, mg/*L* is preferred to the unit parts per million (ppm), to which it is approximately equivalent.

MGY MGY

Initials for "Million Gallons per Year."

MICROORGANISMS (micro-ORGAN-is-zums) MICROORGANISMS

Very small organisms that can be seen only through a microscope. Some microorganisms use the wastes in wastewater for food and thus remove or alter much of the undesirable matter.

MILLION GALLONS MILLION GALLONS

A unit of measurement used in wastewater treatment plant design and collection system capacities or performances.

One million gallons of water is approximately equivalent to:

13,690	Cubic Feet
3.07	Acre-Feet
8,340,000	Pounds of Weight
3,723	Tons of Weight
3,785	Cubic Meters

MINERAL MINERAL

Any substance that is neither animal nor vegetable. Minerals include sand, salt, iron, calcium, and nutrients.

MINERAL CONTENT MINERAL CONTENT

The quantity of dissolved minerals in a sample of water.

MONITOR MONITOR

(1) (See CONDUCTOR)

(2) (See TELEVISION MONITOR)

N

"N" FACTOR "N" FACTOR

A coefficient value representing the pipe or channel roughness in Manning's formula for computing flows in gravity sewers. See FRICTION LOSS and MANNING'S FORMULA.

NET WASTEWATER CONTRIBUTION NET WASTEWATER CONTRIBUTION

In a wastewater collection system, the net wastewater contribution consists of the liquid wastes and liquid-carried wastes transported by the pipelines or received by the pipelines. This value would be the only wastewater found in a collection system if all sources of infiltration, inflow and exfiltration were eliminated.

NET WASTEWATER FLOW NET WASTEWATER FLOW

The actual wastewater flow from a collection system that reaches a wastewater treatment plant. The net wastewater flow includes the net wastewater contribution, infiltration and inflow and does not include losses through exfiltration.

NODULAR (NOD-you-lar) NODULAR

Shaped like a rounded lump, knot or knob. An irregular enlargement.

NOMINAL DIAMETER NOMINAL DIAMETER

Approximate diameter of a pipe; used to describe the size or diameter of a pipe.

NOMOGRAPH (NOME-o-graph) NOMOGRAPH

A graphic representation or means of solving an equation or mathematical relationship. Results are obtained with the aid of a straightedge placed over important known values.

O

OSHA OSHA

The Williams-Steiger **O**ccupational **S**afety and **H**ealth **A**ct of 1970 is a law designed to protect the health and safety of industrial workers and collection system operators. The Act regulates the design, construction, operation and maintenance of industrial plants and wastewater collection and treatment facilities. The Act does not apply directly to municipalities at present (1981), *EXCEPT* in those states that have approved plans and have asserted jurisdiction under Section 18 of the OSHA Act. However, wastewater collection systems have come under stricter regulation in all phases of activity as a result of OSHA standards.

OBSTRUCTION OBSTRUCTION

Any solid object in or protruding into a wastewater flow in a collection line that prevents a smooth or even passage of the wastewater.

OFF LINE OFF LINE

A run of sewer pipe between two manholes is said to be "off line" if it is not located directly under a straight line passing through the exact centers of the two manholes. Sewer alignment does not always pass through the center of a manhole, especially at junctions. Also called "misaligned."

OFFSET OFFSET

(1) A combination of elbows or bends which brings one section of a line of pipe out of line with, but into a line parallel with, another section.

(2) A pipe fitting in the approximate form of a reverse curve, made to accomplish the same purpose.

(3) A pipe joint that has lost its bedding support and one of the pipe sections has dropped or slipped, thus creating a condition where the pipes no longer line up properly.

OFFSET INVERT OFFSET INVERT

A trough or channel in the bottom of a manhole which is not centered in the bottom.

OFFSET JOINT OFFSET JOINT

A pipe joint that is not exactly in line and centered. See DROP JOINT and VERTICAL OFFSET.

OFFSET MANHOLE OFFSET MANHOLE

A manhole located to one side of a pipe run with either "Y" connections to it or the inlet and outlet pipes bent to enter and leave the manhole.

OFFSET PIPE OFFSET PIPE

(See OFF LINE)

OFFSET TROUGH OFFSET TROUGH

(1) When the pipe feeding into a manhole does not exactly match up with the pipe leading out of the manhole, the invert channel must be angled or curved. This is referred to as an "offset trough."

(2) (See OFFSET INVERT)

OHM OHM

The unit of electrical resistance. The resistance of a conductor in which one volt produces a current of one ampere.

OLFACTORY FATIGUE (ol-FAK-tory) OLFACTORY FATIGUE

A condition in which a person's nose, after exposure to certain odors, is no longer able to detect the odor.

ORGANIC WASTE ORGANIC WASTE

Waste material which comes from animal or vegetable sources. Organic wastes generally can be consumed by bacteria and other small organisms. (Inorganic wastes are chemical substances of mineral origin.)

ORIFICE (OR-uh-fiss) ORIFICE

An opening in a plate, wall, or partition. An orifice flange set in a pipe consists of a slot or hole smaller than the pipe diameter. The difference in pressure in the pipe above and at the orifice may be related to flow in the pipe.

OUTFALL OUTFALL

(1) The point, location or structure where wastewater or drainage discharges from a sewer, drain, or other conduit.

(2) The conduit leading to the final disposal area. See OUTFALL SEWER.

OUTFALL SEWER OUTFALL SEWER

A sewer that receives wastewater from a collection system or from a wastewater treatment plant and carries it to a point of ultimate or final discharge in the environment. See OUTFALL.

OUTLET OUTLET

Downstream opening or discharge end of a pipe, culvert, or canal.

OVERFLOW MANHOLE OVERFLOW MANHOLE

A manhole which fills and allows raw wastewater to flow out onto the street or ground.

OVERFLOW RELIEF LINE OVERFLOW RELIEF LINE

Where a system has overload conditions during peak flows, an outlet above the invert, leading to a less loaded manhole or part of the system may be installed. This is usually called an "overflow relief line." Also see CROSS CONNECTION (2).

OXIDATION (ox-i-DAY-shun) OXIDATION

The addition of oxygen, removal of hydrogen, or the removal of electrons from an element or compound. In wastewater treatment, organic matter is oxidized to more stable substances.

OXIDATION-REDUCTION POTENTIAL OXIDATION-REDUCTION POTENTIAL

The electrical potential required to transfer electrons from one compound or element (the oxidant) to another compound or element (the reductant) and used as a qualitative measure of the state of oxidation in wastewater treatment systems.

OXYGEN DEFICIENCY OXYGEN DEFICIENCY

An atmosphere containing oxygen at a concentration of less than 19.5 percent by volume.

P

PACKER PACKER

(See CHEMICAL GROUTING)

PACKING RING PACKING RING

A ring made of asbestos or metal which may be lubricated with Teflon or graphite that forms a seal between the pump shaft and its casing.

PARACHUTE PARACHUTE

A device used to catch wastewater flow to pull a float line between manholes. See FLOAT LINE.

PARSHALL FLUME PARSHALL FLUME

A specially constructed flume or channel used to measure flows in open channels.

PATHOGENIC ORGANISMS (PATH-o-JEN-nick OR-gan-iz-ums) PATHOGENIC ORGANISMS

Bacteria, viruses, or cysts which can cause disease (typhoid, cholera, dysentery). There are [illegible] types of bacteria which do *NOT* cause disease and which are *NOT* called pathogenic. Many beneficial bacteria are found in wastewater treatment processes actively cleaning up organic wastes.

PEAKING FACTOR PEAKING FACTOR

Ratio of a maximum flow to the average flow, such as maximum hourly flow or maximum daily flow to the average daily flow.

PERCOLATION (PURR-ko-LAY-shun) PERCOLATION

The movement or flow of water through soil or rocks.

PHOTOGRAPHIC INSPECTIONS PHOTOGRAPHIC INSPECTIONS

A method of obtaining photographs of a pipeline by pulling a time-lapse motion picture camera through the line. By moving the camera a specific distance at timed intervals, a sequence of photographs covering the full length of the line is obtained.

PHOTOGRAPHIC RECORDS PHOTOGRAPHIC RECORDS

(1) The film strip from a photographic inspection.

(2) Still camera photographs of a sewer television inspection monitor.

PIPE BEDDING PIPE BEDDING
(See BEDDING and BEDDING GRADE)

PIPE BUCKET PIPE BUCKET

(See BUCKET and BUCKET MACHINE)

PIPE CAPACITY PIPE CAPACITY

In a gravity flow sewer system, pipe capacity is the total amount in gallons a pipe is able to pass in a specific time period.

PIPE CLEANING PIPE CLEANING

Removing grease, grit, roots and other debris from a pipe run by means of one of the hydraulic cleaning methods. (See BALLING, HYDRAULIC CLEANING and KITE)

NOTE: While rodding may be used to open a pipe stoppage or to remove roots and greases, it is not known to remove grit and similar debris.

PIPE DEFLECTION PIPE DEFLECTION

(See DEFLECTION)

PIPE DIAMETER PIPE DIAMETER

The nominal or commercially designated inside diameter of a pipe, unless otherwise stated.

PIPE DIP PIPE DIP

(See DIP)

PIPE DISPLACEMENT PIPE DISPLACEMENT

(1) The cubic inches of soil or water displaced by one foot or one section of pipe.
(2) (See DISPLACED PIPE)

PIPE GRADE PIPE GRADE

The angle of a sewer or a single section of a sewer as installed. Usually expressed in a percentage figure to indicate the drop in feet or tenths of a foot per hundred feet. For example, 0.5 percent grade means a drop of one-half foot per 100 feet of length.

PIPE JACK PIPE JACK

A jack used to fasten roller guides to secure an object within a manhole.

PIPE JOINT PIPE JOINT

A place where two sections of pipe are coupled or joined together.

PIPE JOINT SEAL PIPE JOINT SEAL

(1) The tightness or lack of leakage at a pipe joint.
(2) The method of sealing a pipe coupling.

PIPE LINER PIPE LINER

A plastic liner pulled or pushed into a pipe to eliminate excessive infiltration or exfiltration. Other solutions to the problem of infiltration/exfiltration are the use of cast iron pipe or a cement grouting.

PIPE PLUG PIPE PLUG

(1) A temporary plug placed in a sewer pipe to stop a flow while repair work is being accomplished or other functions are performed.
(2) In construction of a new sewer system, service saddles are sometimes installed before a building or a building lateral is in existence. Under such circumstances, a plug will be placed in the off-lead of the saddle of a "Y". In some instances, this plug may be called a "button" or a "stopper."

PIPE PLUG, INFLATABLE PIPE PLUG, INFLATABLE

(See INFLATABLE PIPE STOPPER)

PIPE PLUG, MECHANICAL PIPE PLUG, MECHANICAL

(See MECHANICAL PLUG)

PIPE RODDING PIPE RODDING

A method of opening a plugged or blocked pipe by pushing a steel rod or snake, or pulling same, through the pipe with a tool attached to the end of the rod or snake. Rotating the rod or snake with a tool attached increases effectiveness.

PIPE RUN PIPE RUN

(1) The length of sewer pipe reaching from one manhole to the next. See BARREL.
(2) Any length of pipe, generally assumed to be in a straight line.

PIPE SEAL PIPE SEAL

(See PIPE JOINT SEAL)

PIPE SEALING PIPE SEALING

(See CHEMICAL GROUTING)

PIPE SECTION PIPE SECTION

A single length of pipe between two joints or couplers.

PIPE SINK PIPE SINK

(See DIP)

PLANT PLANT

(See WASTEWATER TREATMENT PLANT)

PLANT HYDRAULIC CAPACITY PLANT HYDRAULIC CAPACITY

The flow or load, in millions of gallons per day (or fraction thereof) that a treatment plant is designed to handle.

PLANT, TREATMENT PLANT, TREATMENT

(See WASTEWATER TREATMENT PLANT)

PLUG PLUG

(See INFLATABLE PIPE STOPPER and MECHANICAL PLUG)

PNEUMATIC EJECTOR (new-MAT-tik ee-JECK-tor) PNEUMATIC EJECTOR

A device for raising wastewater sludge or other liquid by compressed air. The liquid is alternately admitted through an inward-swinging check valve into the bottom of an airtight pot. When the pot is filled compressed air is applied to the top of the liquid. The compressed air forces the inlet valve closed and forces the liquid in the pot through an outward swinging check valve, thus emptying the pot.

POLLUTION POLLUTION

Any change in the natural state of water which interferes with its beneficial reuse or causes its failure to meet water quality requirements.

POLE SHADER POLE SHADER

Separations on the iron core inside the coil of a magnetic starter.

POLYELECTROLYTE (POLY-electro-light) POLYELECTROLYTE

A high-molecular-weight substance that is formed by either a natural or synthetic process. Natural polyelectrolytes may be of biological origin or derived from starch products, cellulose derivatives, and alignates. Synthetic polyelectrolytes consist of simple substances that have been made into complex, high-molecular-weight substances. Often called a POLYMER.

POLYMER (POLY-mer) POLYMER

A high-molecular-weight substance that is formed by either a natural or synthetic process. Natural polymers may be of biological origin or derived from starch products, cellulose derivatives, and alignates. Synthetic polymers consist of simple substances that have been made into complex, high-molecular-weight substances. Often called a POLYELECTROLYTE.

POPULATION EQUIVALENT (HYDRAULIC) POPULATION EQUIVALENT (HYDRAULIC)

A flow of 100 gallons per day is the hydraulic or flow equivalent to the contribution or flow from one person. Population equivalent = 100 gpcd or gallons per capita per day.

POTABLE WATER (PO-ta-ble) POTABLE WATER

Water that does not contain objectionable pollution, contamination, minerals, or infective agents and is considered satisfactory for domestic consumption.

POWER RODDER POWER RODDER

A sewer-cleaning machine fitted with auger rods which are inserted in a sewer line to dislodge and cut roots and debris.

PPM PPM

Initials for "Parts Per Million." The number of weight or volume units of a minor constituent present with each one million units of the major constituent of a solution or mixture. Used to express the results of most water and wastewater analyses, but more recently milligrams per liter (mg/*L*) is the preferred term.

PRECIPITATION PRECIPITATION

(1) The total measurable supply of water received directly from clouds as rain, snow, hail, or sleet; usually expressed as depth in a day, month, or year, and designated as daily, monthly, or annual precipitation.

(2) The process by which atmospheric moisture is discharged onto a land or water surface.

(3) The separation (of a substance) out in solid form from a solution, as by the use of a reagent.

PRESSURE GROUTING PRESSURE GROUTING

(See CHEMICAL GROUTING)

PRESSURE HEAD PRESSURE HEAD

(1) The height of a water surface above a specific point of reference. Usually measured in feet and tenths of a foot.

(2) The head represented by the expression of pressure over weight (p/w), where p is pressure (lbs/sq ft) and w is weight (lbs/cu ft).

PRESSURE MAIN PRESSURE MAIN

(See FORCE MAIN)

PREVENTIVE MAINTENANCE PREVENTIVE MAINTENANCE

Regularly scheduled servicing of machinery or other equipment using appropriate tools, tests and lubricants. This type of maintenance can prolong the useful life of equipment and machinery and increase its efficiency by detecting and correcting problems before they cause a breakdown of the equipment.

PROBE PROBE

A T-shaped tool or rod that is pushed or driven down through the soil to locate underground pipes and utility conduits. Also see SOUNDING ROD.

PROTRUDING SERVICE PROTRUDING SERVICE

The connection of a building lateral to a main sewer line whereby a hole is cut in the main and the end of the building lateral is allowed to extend into the main.

PROTRUDING TAP PROTRUDING TAP

(See PROTRUDING SERVICE)

PUMP PUMP

A mechanical device for causing flow, for raising or lifting water or other fluid, or for applying pressure to fluids.

PUMP PIT PUMP PIT

A dry well, chamber or room below ground level in which a pump is located.

PUMP STATION PUMP STATION

Installation of pumps to lift wastewater to a higher elevation in places where flat land would require excessively deep sewer trenches. Also used to raise wastewater from areas too low to drain into available collection lines. These stations may be equipped with air-operated ejectors or centrifugal pumps. See LIFT STATION.

PUTREFACTION (PEW-tree-FACK-shun) PUTREFACTION

Biological decomposition of organic matter with the production of ill-smelling products associated with anaerobic conditions.

PUTRESCIBLE (pu-TRES-uh-bull) PUTRESCIBLE

Material that will decompose under anaerobic conditions and produce nuisance odors.

Q

QUADRANT QUADRANT

Any of the four more or less equal parts into which something can be divided by two real or imaginary lines that intersect each other at right angles. In television inspection of pipes, for example, the picture of the pipe can be divided into fourths (upper-left, lower-left, upper-right, and lower-right quandrants) to identify the location of observed objects.

QUICK AIR TEST QUICK AIR TEST

The same as a quick test with a packer for chemical grouting except that air pressure is used in place of liquid for a faster test and greater accuracy. Also see CHEMICAL GROUTING.

QUICK TEST QUICK TEST

Use of a packer designed for chemical grouting to pressure test any selected small area of pipeline. Also see CHEMICAL GROUTING.

QUICKSAND QUICKSAND

Sand that has lost its grain-to-grain contact by the buoyancy effect of water flowing upward through the voids. Such material, having some of the characteristics of a fluid, possesses no load-bearing value.

R

"R" FACTOR "R" FACTOR

Refers to pipe or channel "Roughness Factor." See FRICTION LOSS, "N" FACTOR, and ROUGHNESS COEFFICIENT.

R-ZONED R-ZONED

Areas established for residential occupancy.

RAIN RAIN

Particles of liquid water that have become too large to be held by the atmosphere. Their diameter generally is greater than 0.02 inch and they usually fall to the earth at velocities greater than 10 fps in still air. See PRECIPITATION.

RECORDINGS, FLOW RECORDINGS, FLOW

(See FLOW RECORDINGS)

RECORDINGS, PHOTOGRPAHIC RECORDINGS, PHOTOGRAPHIC

(See PHOTOGRAPHIC RECORDS)

RECORDINGS, VIDEO RECORDINGS, VIDEO

(See VIDEO LOG)

RECORDINGS, WRITTEN RECORDINGS, WRITTEN

(See TELEVISION INSPECTION LOG)

REDUCTANT REDUCTANT

A constituent of wastewater or surface waters that uses either free (O_2) or combined oxygen in the process of stabilization.

REGULATOR REGULATOR

A device used in combined sewers to control or regulate the diversion of flow.

RELIEF BY-PASS RELIEF BY-PASS

(See BY-PASS and OVERFLOW RELIEF LINE)

RELIEF LINE RELIEF LINE

(See OVERFLOW RELIEF LINE)

RESISTANCE RESISTANCE

That property of a conductor or wire that opposes the passage of a current, thus causing electrical energy to be transformed into heat.

RETENTION RETENTION

(1) That part of the precipitation falling on a drainage area which does not escape as surface streamflow during a given period. It is the difference between total precipitation and total run-off during the period, and represents evaporation, transpiration, subsurface leakage, infiltration, and, when short periods are considered, temporary surface or underground storage on the area.

(2) The delay or holding of the flow of water and water-carried wastes in a pipe system. This can be due to a restriction in the pipe, a stoppage or a drip. Also, the time water is held or stored in a basin or wet well. This is also called DETENTION.

ROD GUIDE ROD GUIDE

A bent pipe inserted in a manhole to guide hand and power rods into collection lines so the rods can dislodge obstructions.

ROD (SEWER) ROD (SEWER)

A light metal rod, three to five feet long with a coupling at each end. Rods are joined and pushed into a sewer to dislodge obstructions.

RODDING RODDING

(See PIPE RODDING)

RODDING MACHINE RODDING MACHINE

A machine designed to feed a rod into a pipe while rotating the rod. See PIPE RODDING.

RODDING TOOLS RODDING TOOLS

Special tools attached to the end of a rod or snake to accomplish various results in pipe rodding.

ROOF LEADER ROOF LEADER

A downspout or pipe installed to drain a roof gutter to a storm drain or other means of disposal.

ROOT, SEWER ROOT, SEWER

Any part of a root system of a plant or tree that enters a collection system.

ROOT MOP ROOT MOP

When roots from plant life enter a sewer system, the roots frequently branch to form a growth that resembles a string mop.

ROTAMETER (ROW-ta-meter) ROTAMETER

A device used to measure the flow rate of gases and liquids. The gas or liquid being measured flows vertically up a calibrated tube. Inside the tube is a small ball or a bullet-shaped float (it may rotate) that rises or falls depending on the flow rate. The flow rate may be read on a scale behind the middle of the ball or the top of the float.

ROUGHNESS COEFFICIENT ROUGHNESS COEFFICIENT

A value used in Manning's formula to determine energy losses of flowing water due to pipe or channel wall roughness. Also see FRICTION LOSS, "N" FACTOR and MANNING'S FORMULA.

ROUGHNESS FACTOR ROUGHNESS FACTOR

(See ROUGHNESS COEFFICIENT)

RUNOFF RUNOFF

That part of rain or other precipitation that runs off the surface of a drainage area and does not enter the soil or the sewer system as inflow.

S

SADDLE SADDLE

A fitting mounted on a pipe for attaching a new connection. This device makes a tight seal against the main pipe by use of a clamp, adhesive, or gasket and prevents the service pipe from protruding into the main.

SADDLE CONNECTION SADDLE CONNECTION

A building service connection made to a sewer main with a device called a saddle.

SAND TRAP SAND TRAP

A device which can be placed in the outlet of a manhole to cause a settling pond to develop in the manhole invert, thus trapping sand, rocks and similar debris heavier than water. Also may be installed in outlets from car wash areas. Also see GRIT CATCHER.

SANITARY COLLECTION SYSTEM SANITARY COLLECTION SYSTEM

The pipe system for collecting and carrying liquid and liquid-carried wastes from domestic sources to a wastewater treatment plant. Also see WASTEWATER COLLECTION SYSTEM.

SANITARY SEWER SANITARY SEWER

A sewer that carries water and water-carried wastes from residences, commercial buildings, industrial plants, and institutions, together with minor quantities of ground, storm, and surface waters (that are not admitted intentionally) to treatment or disposal facilities.

SATURATED SOIL SATURATED SOIL

Soil that cannot absorb any more liquid. The interstices or void spaces in the soil are filled with water to the point at which runoff occurs.

SCALE SCALE

A combination of mineral salts and bacterial accumulation that sticks to the inside of a collection pipe under certain conditions. Scale, in extreme growth circumstances, creates additional friction loss to the flow of water. Scale may also accumulate on surfaces other than pipes.

SCOOTER SCOOTER

A sewer-cleaning tool whose cleansing action depends on the development of high water velocity around the outside edge of a circular shield. The metal shield is rimmed with a rubber coating and is attached to a framework on wheels (like a child's scooter). The angle of the shield is controlled by a chain-spring system which regulates the head of water behind the scooter and thus, the cleansing velocity of the water flowing around the shield.

SCUM SCUM

(1) A layer or film of foreign matter (such as grease, oil) that has risen to the surface of water or wastewater.

(2) A residue deposited on the ledge of a sewer, channel, or wet well at the water surface.

(3) A mass of solid matter that floats on the surface.

SEAL SEAL

(See PIPE JOINT SEAL)

SEALING SEALING

(See CHEMICAL GROUTING)

SEASONAL WATER TABLE SEASONAL WATER TABLE

A groundwater table that has seasonal changes in depth or elevation.

SEDIMENT SEDIMENT

Solid material settled from suspension in a liquid.

SEDIMENTATION (SED-uh-men-TAY-shun) SEDIMENTATION

The process of settling and depositing suspended matter carried by wastewater, by gravity. Sedimentation usually occurs when the velocity of the wastewater is reduced below the point at which it can transport the suspended material.

SEISMIC (SIZE-mick) SEISMIC

Relating to an earthquake or violent earth vibration such as an explosion.

SELECT BACKFILL SELECT BACKFILL

Material used in backfilling of an excavation, selected for desirable compaction or other characteristics.

SEPTIC (SEP-tick) SEPTIC

This condition is produced by anaerobic bacteria. If severe, the wastewater turns black, gives off foul odors, contains little or no dissolved oxygen, and creates a high oxygen demand.

SEPTIC TANK SEPTIC TANK

A settling tank in which settled sludge is in intimate contact with the wastewater flowing through the tank and the organic solids are decomposed by anaerobic bacterial action.

SERVICE SERVICE

Any individual person, group of persons, thing, or groups of things served with water through a single pipe, gate, valve, or similar means of transfer from a main distribution system. Also see BUILDING SERVICE.

SERVICE CONNECTION SERVICE CONNECTION

(See BUILDING SEWER)

SERVICE ROOT SERVICE ROOT

A root entering the sewer system in a service line and growing down the pipe and into the sewer main.

SEWAGE SEWAGE

The used water and water-carried solids from homes that flow in sewers to a treatment plant. The preferred term is WASTEWATER.

SEWER SEWER

A pipe or conduit that carries wastewater or drainage water. The term "collection line" is often used also.

SEWER BALL SEWER BALL

A spirally grooved inflatable semi-hard rubber ball designed for hydraulic cleaning of sewer pipes. See BALLING.

SEWER CLEANOUT SEWER CLEANOUT

A capped opening in a sewer main that allows access to the pipes for rodding and cleaning. Usually such cleanouts are located at terminal pipe ends or beyond terminal manholes. Also called a FLUSHER BRANCH.

SEWER GAS SEWER GAS

(1) Gas in collection lines (sewers) that results from the decomposition of organic matter in the wastewater. When testing for gases found in sewers, test for lack of oxygen and also for explosive and toxic gases.

(2) Any gas present in the wastewater collection system, even though it is from such sources as gas mains, gasoline, and cleaning fluid.

SEWER JACK SEWER JACK

A device placed in manholes which supports a yoke or pulley that keeps wires or cables from rubbing against the inlet or outlet of a sewer.

SEWER MAIN SEWER MAIN

A sewer pipe to which building laterals are connected. Also called a COLLECTION MAIN.

SEWER SYSTEM SEWER SYSTEM

(See COLLECTION SYSTEM)

SEWERAGE SEWERAGE

System of piping with appurtenances for collecting, moving and treating wastewater from source to discharge.

SHEAVE (SHE-v) SHEAVE

V-belt drive pulley which is commonly made of cast iron or steel.

SHEETING SHEETING

Solid material, such as wooden sheets or metal plates, used to hold back soil and prevent cave-ins.

SHIELD SHIELD

(1) A fabricated protective crib made of steel or aluminum plate. The shield is placed on the bottom of open trenches in unstable soil areas where conventional protective shoring is not sufficient. From inside the shield, workers can safely install or repair pipelines.

(2) A device used to protect workers from sources of electrical, mechanical, or heat energy.

SHIM SHIM

Thin metal sheets which are inserted between two surfaces to align or space the surfaces correctly. Shims can be used anywhere a spacer is needed. Usually shims are 0.001 to 0.020 inches thick.

SHORING SHORING

Material such as boards, planks or plates and hydraulic jacks used to hold back soil around trenches and to protect workers in a trench from cave-ins. Also see SHEETING.

SILTING SILTING

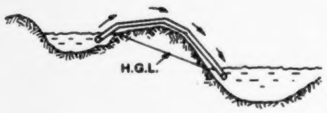
Silting takes place when the pressure of infiltrating waters is great enough to carry silt, sand and other small particles from the soil into the sewer system. Where lower velocities are present in the sewer pipes, settling of these materials results in silting of the sewer system.

SINK SINK

(See DIP)

SIPHON SIPHON

A pipe or conduit through which water will flow above the hydraulic grade line (H.G.L.) under certain conditions. Water (or other liquid) is first forced to flow or is sucked through the pipe by creation of a vacuum. As long as no air enters the pipe to interrupt flow, atmospheric pressure on the liquid at the elevated (higher) end of the siphon will cause the flow to continue.



SLEEVE SLEEVE

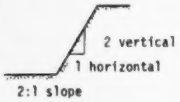
(1) A pipe fitting for joining two pipes of the same nominal diameter in a straight line.

(2) A tube into which a pipe is inserted.

(3) A device to protect a shaft at its bearing or wear points.

SLOPE SLOPE

The slope or inclination of a sewer trench excavation is the ratio of the vertical distance to the horizontal distance or "rise over run." See GRADE (2).



SLUDGE (sluj) SLUDGE

The settleable solids separated from liquids during processing or the deposits of foreign materials on the bottoms and edges of wastewater collection lines and appurtenances.

SMOKE TEST SMOKE TEST

A method of blowing smoke into a closed-off section of a sewer system to locate sources of surface inflow.

SNAKE SNAKE

A stiff but flexible cable that is inserted into sewers to clear stoppages.

SOAP CAKE OR SOAP BUILDUP SOAP CAKE OR SOAP BUILDUP

A combination of detergents and greases that accumulate in sewer systems and build up over a period of time to cause severe restrictions.

SOIL DISPLACEMENT SOIL DISPLACEMENT

Movement of soil from one place to another. Generally accompanies SILTING of a sewer system. Where infiltration is taking place and silt is carried into a sewer system, such silt or soil is removed from the ground around the sewer pipe and the result is soil displacement.

SOIL PIPE SOIL PIPE

(1) A type of wastewater or service connection pipe made of a low grade of cast iron.

(2) In plumbing, a pipe that conveys the discharge of toilets or similar fixtures, with or without the discharges from other fixtures.

SOIL POLLUTION SOIL POLLUTION

The leakage (exfiltration) of raw wastewater into the soil or ground area around a sewer pipe.

SOIL STABILIZATION SOIL STABILIZATION

Injection of chemical grouts into saturated or otherwise unstable soil. The process seals out water and prevents further instability.

SOUNDING ROD SOUNDING ROD

A T-shaped tool or shaft that is pushed or driven down through the soil to locate underground pipes and utility conduits. Also see PROBE.

SPECIFIC GRAVITY SPECIFIC GRAVITY

Weight of a particle or substance in relation to the weight of an equal volume of water. Water has a specific gravity of 1.000 at 40°C (or 39°F). Wastewater particles or substances usually have a specific gravity of 0.5 to 2.5.

SPHERULITIC (SFEAR-you-LIT-tick) SPHERULITIC

A rounded aggregate of particles; or, crystals in the form of a ball.

SPOIL SPOIL

Excavated material such as soil from the trench of a sewer.

SPRINGLINE SPRINGLINE

Theoretical center of a pipeline; or, the guideline for laying a course of bricks.

STABILIZE STABILIZE

To convert to a form that resists change. Organic material is stabilized by bacteria which convert the material to gases and other relatively inert substances. Stabilized organic material generally will not give off obnoxious odors.

STATIC HEAD STATIC HEAD

When water is not moving, the vertical distance (in feet) from a point to the water surface is the static head. Also see DYNAMIC HEAD.

STATION STATION

A point of reference or location in a pipeline is sometimes called a "station." As an example, a building service located fifty-one feet downstream from a manhole could be reported to be at "station fifty-one."

STATION, LIFT STATION, LIFT

(See LIFT STATION)

STILLING WELL STILLING WELL

A pipe, chamber, or compartment with a relatively small inlet or inlets connected to a main body of water, such as water in a wet well. The purpose of a stilling well is to dampen waves or surges while allowing the water level within the well to rise and fall with the major fluctuations of the main body of water. Stilling wells are used with water flow- and depth-measuring devices to improve the accuracy of measurement.

STOPPAGE STOPPAGE

(1) Partial or complete interruption of flow as a result of some obstruction in a sewer.

(2) When a sewer system becomes plugged and the flow backs up, it is said to have a "stoppage." Also see BLOCKAGE.

STORM COLLECTION SYSTEM STORM COLLECTION SYSTEM

A system of gutters, catch basins, yard drains, culverts and pipes for the purpose of conducting storm waters from an area, but intended to exclude domestic and industrial wastes.

STORM RUNOFF STORM RUNOFF

The amount of runoff that reaches the point of measurement within a relatively short period of time after the occurrence of a storm or other form of precipitation. Also called "direct runnoff."

STORM SEWER STORM SEWER

A sewer that carries storm water and surface water, street wash and other wash waters, or drainage, but excludes domestic wastewater and industrial wastes. Also called "storm drain."

STORM WATER STORM WATER

The excess water running off from the surface of a drainage area during and immediately after a period of rain. See STORM RUNOFF.

STORM WATER INLET STORM WATER INLET

A device that admits surface waters to the storm water drainage system. Also see CURB INLET and CATCH BASIN.

STRINGERS STRINGERS

Horizontal shoring members, usually square, rough cut timber, that are used to hold solid sheeting, braces or vertical shoring members in place. Also called WALERS.

STRUCTURAL DEFECT STRUCTURAL DEFECT

A flow or imperfection of a structure or design which was built into a project, pipeline or other collection system appurtenance.

STRUCTURAL FAILURE STRUCTURAL FAILURE

A condition that exists when one or more components of a system break down or fail to perform as expected. A structural failure may result from defective parts or design or may result from other circumstances that occur after the completion of construction.

SUBSOIL GEOLOGY SUBSOIL GEOLOGY

The study of soil conditions existing below the surface of the ground at any selected site.

SUBSYSTEM SUBSYSTEM

An extensive underground sewer system connected to the main collection system, but not considered part of the main system. An example might be the underground sewer system of a mobile home park.

SUCKER RODS SUCKER RODS

Rigid, coupled sewer rods of metal or wood used for clearing stoppages. Usually available in 3 ft, 39 in, 4 ft, 5 ft and 6 ft lengths.

SUCTION HEAD SUCTION HEAD

The *POSITIVE* pressure (in feet or pounds per square inch (psi)) on the suction side of a pump. The pressure can be measured from the center line of the pump *UP TO* the elevation of the hydraulic grade line on the suction side of the pump.

SUCTION LIFT SUCTION LIFT

The *NEGATIVE* pressure (in feet or inches of mercury vacuum) on the suction side of a pump. The pressure can be measured from the center line of the pump *DOWN TO* the elevation of the hydraulic grade line on the suction side of the pump.

SURCHARGE SURCHARGE

Sewers are surcharged when the supply of water to be carried is greater than the capacity of pipes to carry the flow. The surface of the wastewater in manholes rises above the top of the sewer pipe, and the sewer is under pressure or a head, rather than at atmospheric pressure.

SURCHARGED MANHOLE SURCHARGED MANHOLE

A manhole in which the rate of the water entering is greater than the capacity of the outlet under gravity flow conditions. When the water in the manhole rises above the top of the outlet pipe, the manhole is said to be "surcharged."

SURFACE RUNOFF SURFACE RUNOFF

(1) The precipitation that is unable to be absorbed by the soil and flows across the surface by gravity.

(2) The water that reaches a stream by traveling over the soil surface or falls directly into the stream channels, including not only the large permanent streams but also the tiny rills and rivulets.

(3) Water that remains after infiltration, interception, and surface storage have been deducted from total precipitation.

SURFACED DEFECT SURFACED DEFECT

A break or opening in a sewer pipe where the covering soil has been washed away and the opening or break is exposed on the ground surface.

SURFACED VOID SURFACED VOID

A dip or depression in the ground that appears when silting has taken place to a degree that a void is caused in the subsoil and through successive cave-ins, the void reaches the surface of the ground.

SURVEILLANCE TELEVISION EQUIPMENT SURVEILLANCE TELEVISION EQUIPMENT

Economical closed-circuit television equipment designed for surveillance or security work in commercial facilities. Picture resolutions generally range from 250 to 350 lines.

SUSPENDED SOLIDS SUSPENDED SOLIDS

Solid particles that either float on the surface of, or are in suspension in water, wastewater or other liquids. Suspended solids are largely removable by laboratory filtering.

T

TAG LINE TAG LINE

A line, rope or cable that follows equipment through a sewer so that equipment can be pulled back out if it encounters an obstruction or becomes stuck. Equipment is pulled forward with a pull line.

TAP TAP

A small hole in a sewer where a wastewater service line from a building is connected (tapped) into a lateral or branch sewer.

TELEMETERING EQUIPMENT TELEMETERING EQUIPMENT

Equipment that translates physical measurements into electrical impulses that are transmitted to dials or recorders.

TELEMETRY TELEMETRY

The practice of transmitting and receiving a metered variable.

TELEVISION INSPECTION TELEVISION INSPECTION

An inspection of the inside of a sewer pipe made by pulling a closed-circuit television camera through the pipe.

TELEVISION INSPECTION LOG TELEVISION INSPECTION LOG

A record of a pipeline television inspection which provides date, line location, footage distances, pipe quadrant locations and descriptions of all conditions observed in the inspection. When this log is written, it is called a "written recording." When it is voice recorded on a tape, it is called a "voice tape recording." If the picture is recorded with a video tape recorder with audio remarks, it is called a "video-voice inspection record." Where data-viewing reporting is used, it is called a VIDEO LOG.

TELEVISION MONITOR TELEVISION MONITOR

The television set or kinescope where the picture is viewed on a closed-circuit system.

TEMPORARY GROUNDWATER TABLE TEMPORARY GROUNDWATER TABLE

(1) During and for a period following heavy rainfall or snow melt, the soil is saturated at elevations above the normal, stabilized or seasonal groundwater table, often from the surface of the soil downward. This is referred to as a temporary condition and thus is a temporary groundwater table.

(2) When a collection system serves agricultural areas in its vicinity, irrigation of these areas can cause a temporary rise in the elevation of the groundwater table.

TERMINAL CLEANOUT TERMINAL CLEANOUT

When a manhole is not provided at the upstream end of a sewer main, a cleanout is usually provided. This is called a "terminal cleanout" or a FLUSHER BRANCH.

TERMINAL MANHOLE	TERMINAL MANHOLE

A manhole located at the upstream end of a sewer and having no inlet pipe. Also called a DEADEND MANHOLE.

TEST BORE	TEST BORE

A hole or bore made to sample and determine the structure of underground soil conditions.

TIDE GATE	TIDE GATE

A gate with a flap suspended from a free-swinging horizontal hinge, usually placed at the end of a conduit discharging into a body of water having a fluctuating surface elevation. The gate is usually closed because of outside water pressure, but will open when the water head inside the pipe is great enough to overcome the outside pressure, the weight of the flap, and the friction of the hinge. Also called a BACKWATER GATE.

TOPOGRAPHIC GEOLOGY (TOP-o-GRAPH-ick)	TOPOGRAPHIC GEOLOGY

A study of the rock and soil formations of an area for purposes of mapping underground conditions with identifications and elevations. Often called a "geological survey."

TOPOGRAPHY (toe-POG-gra-fee)	TOPOGRAPHY

The description or features of an area, such as the hills, valleys, mountains and slope of the land surfaces.

TOTAL CONTRIBUTION	TOTAL CONTRIBUTION

All water and wastewater entering a sewer system from a specific facility, subsystem or area. This includes domestic and industrial wastewaters, inflow and filtration reaching the main collection system.

TOTAL FLOW	TOTAL FLOW

The total flow passing a selected point of measurement in the collection system during a specified period of time.

TOTAL DYNAMIC HEAD (T.D.H.)	TOTAL DYNAMIC HEAD

When a pump is lifting or pumping water, the vertical distance (in feet) from the elevation of the energy grade line on the suction side of the pump to the elevation of the energy grade line on the discharge side of the pump.

TOTALIZER	TOTALIZER

A device that continuously sums or adds the flow past the flow meter in gallons or million gallons or some other unit of measurement. Also called an "integrator."

TRAP	TRAP

(1) In the wastewater collection system of a building, plumbing codes require every drain connection from an appliance or fixture to have a trap. The trap in this case is a gooseneck that holds water to prevent vapors or gases in a collection system from entering the building.

(2) Various other types of special traps are used in collection systems such as GRIT TRAP or SAND TRAP.

TRAP, DIP	TRAP, DIP

(See DIP)

TRAP, HANDHOLE	TRAP, HANDHOLE

(See HANDHOLE TRAP)

TRENCH JACK	TRENCH JACK

Mechanical screw device used to hold shoring in place.

TRUNK SEWER	TRUNK SEWER

A sewer that receives many tributary branches and serves a large territory. See MAIN SEWER.

TRUNK SYSTEM	TRUNK SYSTEM

A system of major sewers serving as transporting lines and not as local or lateral sewers.

TURBID	TURBID

Having a cloudy or muddy appearance.

TURBIDITY UNITS TURBIDITY UNITS

Turbidity units are a measure of cloudiness of water. Turbidity units, if measured by a nephelometric (reflected light) instrumental procedure, are expressed in nephelometric turbidity units (NTU). Those turbidity units obtained by other instrumental methods or visual methods are expressed in Jackson Turbidity Units (JTU) and sometimes as Formazin Turbidity Units (FTU). The FTU nomenclature comes from the Formazin polymer used to prepare the turbidity standards for instrument calibration.

TWO-WAY CLEANOUT TWO-WAY CLEANOUT

An opening in pipes or sewers designed for rodding or working a snake into the pipe in either direction. Two-way cleanouts are most often found in building lateral pipes at or near to a property line.

U

U-TUBE U-TUBE

(1) A pipe shaped like a U that is constructed in a force main to raise the dissolved oxygen concentration in the wastewater.

(2) U-tube manometers are used to indicate the pressure of a gas or liquid in a confined space.

UNDERMINED UNDERMINED

(1) A condition that occurs when the bedding support under a pipe or manhole has been removed or washed away. Conditions leading to or causing this are believed to be the presence of excess water during backfill. Other causes are horizontal boring operations, excavations adjacent to the pipe or manhole and exfiltration or infiltration at drop joints.

(2) When flow through a broken section of pipe carries away soil around the break leaving a void or empty space, the surfaces over the void are said to be "undermined."

UNDISTURBED SOIL UNDISTURBED SOIL

Soil, at any depth, which has not been excavated or disturbed by excavation or construction.

UPRIGHTS UPRIGHTS

Vertical shoring members that may be solid (SHEETING) or spaced from 2 to 8 feet apart to prevent cave-ins.

UPSTREAM UPSTREAM

The direction against the flow of water; or, toward or in the higher part of a sewer or collection system.

V

V-NOTCH WEIR V-NOTCH WEIR

A triangular weir with a "V" notch calibrated in gallons per minute readings. By holding the weir in a pipe with rubber seals forcing a flow to pass through the "V", a measure of the gallonage flowing through the pipe can be read on the basis of the depth of water flowing over the weir.

VAC-ALL VAC-ALL

Equipment that removes solids from a manhole as they enter the manhole from a hydraulic cleaning operation. Most of the wastewater removed from the manhole by the operation is separated from the solids and returned to the sewer.

VEGETABLE WASTES VEGETABLE WASTES

Vegetable matter entering a collection system. This term is usually used to distinguish such types of waste from animal, industrial, commercial and other types of waste solids.

VEHICLE, LIQUID VEHICLE, LIQUID

(See LIQUID VEHICLE)

VELOCITY HEAD VELOCITY HEAD

A vertical height (in feet) equal to the square of the velocity of flowing water divided by twice the acceleration due to gravity ($V^2/2g$).

VENTS, MANHOLE VENTS, MANHOLE

(See MANHOLE VENTS)

VENTS, WASTELINE SYSTEM VENTS, WASTELINE SYSTEM

(See WASTELINE VENT)

VERTICAL OFFSET VERTICAL OFFSET

A pipe joint in which one section is connected to another at a different elevation, such as a DROP JOINT.

VIDEO INSPECTION VIDEO INSPECTION

A television inspection.

VIDEO LOG VIDEO LOG

A magnetic tape picture recording of a television inspection where data-view reporting has been included as part of the visual record. Also see DATA-VIEW.

VIDEO TAPE VIDEO TAPE

A magnetic tape for recording television pictures. Standard tapes also have a capacity to record a voice with the picture, or an "audio" accompaniment.

VOID VOID

A pore or open space in rock or granular material that is not occupied by solid matter. It may be occupied by air, water, or other gaseous or liquid material. Also called "interstice" or "void space."

VOLTAGE VOLTAGE

The electrical pressure available to cause a flow of current (amperage) when an electrical circuit is closed. See ELECTROMOTIVE FORCE (E.M.F.)

VOLUTE (vol-LOOT) VOLUTE

The spiral-shaped casing surrounding a pump impeller that collects the water discharged by the impeller.

W

WALERS (WAY-lers) WALERS

Horizontal shoring members, usually square, rough cut timber, that are used to hold solid sheeting, braces or vertical shoring members in place. Also called STRINGERS.

WASTELINE CLEANING WASTELINE CLEANING

An opening or point of access in a building wastewater pipe system for rodding or snake operation.

WASTELINE SYSTEM WASTELINE SYSTEM

(See BUILDING WASTEWATER COLLECTION SYSTEM)

WASTELINE TRAP WASTELINE TRAP

(See TRAP (1))

WASTELINE VENT WASTELINE VENT

Most plumbing codes require a vent pipe connection of adequate size and located downstream of a trap in a building wastewater system. This vent prevents the accumulation of gases or odors and is usually piped through the roof and out of doors.

WASTEWATER WASTEWATER

The used water and water-carried solids from a community that flow to a treatment plant. Storm water, surface water, and groundwater infiltation also must be included in the wastewater that enters a plant. The term "sewage" usually refers to household wastes, but this word is being replaced by the term "wastewater."

WASTEWATER COLLECTION SYSTEM WASTEWATER COLLECTION SYSTEM

The pipe system for collecting and carrying water and water-carried wastes from domestic and industrial sources to a wastewater treatment plant.

WASTEWATER FACILITIES WASTEWATER FACILITIES

The pipes, conduits, structures, equipment, and processes required to collect, transport, and treat domestic and industrial wastes, and dispose of the effluent.

WASTEWATER TREATMENT PLANT WASTEWATER TREATMENT PLANT

(1) An arrangement of pipes, equipment, devices, tanks and structures for treating wastewater, industrial wastes, and sludge.

(2) A water pollution control plant.

WATER TABLE WATER TABLE

(See GROUNDWATER TABLE)

WATER TABLE DEPTH WATER TABLE DEPTH

(See GROUNDWATER DEPTH)

WATER TABLE ELEVATION WATER TABLE ELEVATION

(See GROUNDWATER ELEVATION)

WATER TABLE HEAD WATER TABLE HEAD

(See PRESSURE HEAD)

WAYNE BALL WAYNE BALL

A spirally grooved, inflatable, semi-hard rubber ball designed for hydraulic cleaning of sewer pipes. See BALLING and SEWER BALL.

WEIR (Weer) WEIR

(1) A wall or plate placed in an open channel and used to measure the flow. The depth of flow over the weir can be used to calculate the flow rate, or a chart or conversion table may be used. (2) A wall or obstruction used to control flow (from clarifiers) to assure uniform flow and avoid short-circuiting.

WELL POINT WELL POINT

A hollow, pointed rod with a perforated (containing many small holes) tip. A well point is driven into an excavation where water seeps into the tip and is pumped out of the area. Used to lower the water table and reduce flooding during an excavation.

WET PIT WET PIT

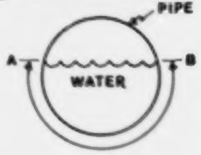
(See WET WELL)

WET WELL WET WELL

A compartment or room in which wastewater is collected, and to which the suction pipe of a pump may be connected. Also, a submersible pump may be located in a wet well.

WETTED PERIMETER WETTED PERIMETER

The length of the wetted portion of a pipe covered by flowing wastewater.



Wetted Perimeter = Distance from A to B

WICK EFFECT WICK EFFECT

(See CAPILLARY EFFECT)

Y

"Y" CONNECTION "Y" CONNECTION

Another name for a BUILDING SERVICE.

Z

ZONE OF SATURATION ZONE OF SATURATION

(1) Where raw wastewater is exfiltrating from a sewer pipe, the area of soil that is moistened around the leak point is often called the "zone of saturation."

(2) The area of soil saturated with water.

APPLICATIONS OF ARITHMETIC TO COLLECTION SYSTEMS

by

Kenneth D. Kerri

TABLE OF CONTENTS

APPLICATIONS OF ARITHMETIC TO COLLECTION SYSTEMS

Page

OBJECTIVES 475

A.0 Why Arithmetic 476

A.1 Basic Arithmetic 476

- A.10 Addition 476
- A.11 Subtraction 476
- A.12 Multiplication 477
- A.13 Division 477
- A.14 Multiplication and Division 477
- A.15 Actual Problems 477
- A.16 Percentage 478
- A.17 Sample Problems Involving Percent 478

A.2 Areas 479

- A.20 Units 479
- A.21 Rectangle 479
- A.22 Triangle 479
- A.23 Circle 480
- A.24 Cylinder 480
- A.25 Cone 481
- A.26 Sphere 481

A.3 Volumes 481

- A.30 Rectangle 481
- A.31 Prism 482
- A.32 Cylinder 482
- A.33 Cone 482
- A.34 Sphere 482

A.4 Metric System 482

- A.40 Measures of Length 483
- A.41 Measures of Capacity or Volume 483
- A.42 Measures of Weight 483
- A.43 Temperature 483
- A.44 Milligrams per Liter 484

A.5 Weight-Volume Relations 484
A.6 Force, Pressure, and Head 484
A.7 Velocity and Flow Rate 485
  A.70 Velocity 485
  A.71 Flow Rate 486
A.8 Pumps 486
  A.80 Pressure 486
  A.81 Work 487
  A.82 Power 487
  A.83 Horsepower 487
  A.84 Head 487
  A.85 Pump Characteristics 488
  A.86 Evaluation of Pump Performance 489
  A.87 Pump Speed - Performance Relationships 490
  A.88 Friction or Energy Losses 491
A.9 Steps in Solving Problems 491
  A.90 Identification of Problems 491
  A.91 Selection of Formula 491
  A.92 Arrangement of Formula 491
  A.93 Unit Conversions 494
  A.94 Calculations 494
  A.95 Significant Figures 494
  A.96 Check Your Results 495
A.10 Basic Conversion Factors (English System) 495
A.11 Summary of Formulas (English System) 495
  A.110 Length 495
  A.111 Area 495
  A.112 Volume 495
  A.113 Velocity and Flow 496
  A.114 Slope or Grade 496
  A.115 Chemical Dose 496
  A.116 Excavation and Paving 496
  A.117 Electricity 496
  A.118 Pumps 496
  A.119 Storage Tanks, Wet Wells and Storage Water Basins 496
A.12 Solutions to Problems 496
  A. Population Equivalent 496
  B. Velocity and Flow 496

C. Pipes 499
D. Slope or Grade 499
E. Leak Test 500
F. Map and Blueprint Reading 501
G. Chemical Doses 501
H. Excavation and Paving 501
I. Electricity 503
J. Pumps 503
K. Ventilation 506
L. Costs 506
M. Performance Indicators 507
A.13 Additional Reading 507
A.14 Practice Problems 507
A.15 Answers to Practice Problems 509

OBJECTIVES

Applications of Arithmetic to Collection Systems

After completion of this section, you should be able to do the following:

1. Do simple addition, subtraction, multiplication and division,
2. Calculate perimeters, circumferences, areas and volumes,
3. Analyze mathematical problems and solve them, and
4. Solve collection system problems regarding:
   a. Excavations and paving,
   b. Chemical doses,
   c. Electricity,
   d. Costs,
   e. Hydraulics,
      1) Slopes
      2) Velocities
      3) Flow rates
      4) Wet wells
      5) Pumps
   f. Maps and blueprints.

APPLICATIONS OF ARITHMETIC TO COLLECTION SYSTEMS

A.0 WHY ARITHMETIC?

Actually most collection system operators use very little arithmetic when doing their day-to-day jobs. If you can add, subtract, multiply and divide, you can solve all of the problems in this section. An electronic calculator can do the addition, subtraction, multiplication and division for you if you can write the formula or equation to be solved.

Collection system operators need to know arithmetic in order to calculate slopes of trenches or pipes and also velocities and flows in sewers. Other examples of uses of arithmetic include the determination of proper chemical doses to control roots or odors. When estimating the cost of a sewer repair job, the costs must be calculated for budgeting purposes. To order bedding or backfill material, the appropriate quantities have to be determined so there are no unnecessary delays from insufficient materials or excess material remaining when the job is completed. Calculations are important when calibrating and comparing performance of new pumps and flow meters with specifications. From time to time equipment performance must be reverified. As you can see, periodically certain jobs that collection system operators must do require some knowledge of and ability to do simple arithmetic. After you have worked an actual collection system arithmetic problem in the field, you should verify your calculations, examine your answer to see if it appears reasonable, and if possible, have another operator review your work before taking any action.

In this section we have tried to show you how to solve problems actually encountered by collection system operators in the field. Hopefully, questions on certification and civil service exams will not be any more difficult.

An objective of this section is to provide you with a quick review of some basic arithmetic principles and examples of typical collection system problems. This appendix is not intended to be an arithmetic textbook. Some operators will be able to skip over the review section on addition, subtraction, multiplication and division. Others may need more help in these and other areas. Basic arithmetic textbooks are available at every local library or bookstore and can be referred to if needed. Deserving special mention is *MATHEMATICS FOR WATER AND WASTEWATER TREATMENT PLANT OPERATORS*[1] which provides considerable detail on how to do basic calculations.

A.1 BASIC ARITHMETIC[2]

In this Section we are going to provide you with basic arithmetic problems involving addition, subtraction, multiplication and division. You may work the problems "by hand" if you wish, but we recommend you use an electronic pocket calculator. The operating or instructional manual for your calculator should outline the step-by-step procedures to follow. All calculators use similar procedures, but most of them are slightly different from others.

We will start with very basic, simple problems. Try working the problems and then comparing your answers with the given answers. If you can work these problems, you should be able to work the more difficult problems in the text of this training manual by using the same procedures.

A.10 Addition

2	6.2	16.7	6.12	43
3	8.5	38.9	38.39	39
5	14.	55.6	44.51	34
				38
				39
2.12	0.12	63	120	37
9.80	2.0	32	60	29
11.92	2.12	95	180	259
4	23	16.2	45.98	70
7	79	43.5	28.09	50
2	31	67.8	114.00	40
13	133	127.5	188.07	80
				240

A.11 Subtraction

7	12	25	78	83
−5	− 3	− 5	−30	−69
2	9	20	48	14
61	485	4.3	3.5	123
−37	−296	−0.8	−0.7	−109
24	189	3.5	2.8	− 14
8.6	11.92	27.32	3.574	75.132
−8.22	− 3.70	−12.96	−0.042	−49.876
0.38	8.22	14.36	3.532	25.256

---

[1] *MATHEMATICS FOR WATER AND WASTEWATER TREATMENT PLANT OPERATORS, Book 1 — Fundamentals and Book 2 — Advanced, by Joanne Kirkpatrick, published by Ann Arbor Science Publishers Inc./Butterworth's Publishing Inc., 10 Tower Office Park, Woburn, MA 01801. Price $22.50 for each book.*

[2] *Major portions of this appendix are taken from OPERATION OF WASTEWATER TREATMENT PLANTS, Volume I, Appendix, "How To Solve Wastewater Treatment Plant Problems." This manual is available from Kenneth D. Kerri, California State University, Sacramento, 6000 J Street, Sacramento, CA 95819-2694. Price for 10 chapter Volume 1, $20.00.*

A.12 Multiplication

(3)(2)[a] = 6

(10)(5) = 50

(2)(22.99) = 45.98

(16)(17.1) = 273.6

(40)(2.31) = 92.4

(4)(7) = 28

(10)(1.3) = 13

(6)(19.5) = 117

(50)(20,000) = 1,000,000

(80)(0.433) = 34.6

(40)(20)(6) = 4,800

(4,800)(7.48) = 35,904

(1.6)(2.3)(8.34) = 30.6912

(0.001)(200)(8.34) = 1.668

(0.785)(7.48)(60) = 352.308

(12,000)(500)(60)(24) = 8,640,000,000 or 8.64×10^9

(4)(1000)(1000)(454) = 1,816,000,000 or 1.816×10^9

NOTE: The term, $\times 10^9$, means that the number is multiplied by 10^9 or 1,000,000,000. Therefore $8.64 \times 10^9 = 8.64 \times 1{,}000{,}000{,}000 = 8{,}640{,}000{,}000$.

A.13 Division

$$\frac{6}{3} = 2 \qquad \frac{48}{12} = 4$$

$$\frac{50}{25} = 2 \qquad \frac{300}{20} = 15$$

$$\frac{20}{7.1} = 2.8 \qquad \frac{11{,}400}{188} = 60.6$$

$$\frac{1{,}000{,}000}{17.5} = 57{,}143 \qquad \frac{861{,}429}{30{,}000} = 28.7$$

$$\frac{4{,}000{,}000}{74{,}880} = 53.4 \qquad \frac{1.67}{8.34} = 0.20$$

$$\frac{80}{2.31} = 34.6 \qquad \frac{62}{454} = 0.137$$

$$\frac{250}{17.1} = 14.6 \qquad \frac{4{,}000{,}000}{14.6} = 273{,}973$$

NOTE: When we divide ⅓ = 0.3333, we get a long row of 3s. Instead of the row of 3s, we "round-off" our answer so ⅓ = 0.33. For a discussion of rounding off numbers, see Section A.95, "Significant Figures."

A.14 Multiplication and Division

Many of the problems we work in the wastewater field involve both multiplication and division. Sometimes addition or subtraction is also involved. To work these types of problems:

1. Do all the addition and subtraction above and below the line,
2. Do all the multiplication above and below the line, and
3. Perform the division.

Instructions for your electronic calculator can provide you with the detailed procedures.

$$\frac{(3)(4)}{2} = 6 \qquad \frac{64}{(8)(4)} = 2$$

$$\frac{(2+3)(4)}{5} = 4 \qquad \frac{(54)}{(4+2)(3)} = 3$$

$$\frac{(7-2)(8)}{4} = 10 \qquad \frac{48}{(8-3)(4)} = 2.4$$

$$\frac{(9)(8)-(6)(6)}{3} = 12 \qquad \frac{(16)(6)}{(8)(7)-(4)(4)} = 2.4$$

$$\frac{(20)}{(0.85)(8.34)} = 2.82 \qquad \frac{30-27}{(1.6)(8.34)} = 0.22$$

$$\frac{(14)(2)}{(13.53-12.98)(8.34)} = 6.10$$

$$\frac{(13)(100)}{(120)(8.34)} = 1.3$$

$$\frac{861{,}429}{(500)(60)} = 28.7$$

$$\frac{(4)(1{,}000{,}000)}{74{,}880} = 53.4$$

$$\frac{(15{,}000)(7.48)(24)}{(1.4)(1{,}000{,}000)} = 1.9$$

$$\frac{(225-25)(100)}{225} = 88.9$$

$$\frac{12}{(0.432)(8.34)} = 3.3$$

$$\frac{(1800)(0.5)(8.34)}{(110)(2.0)(8.34)} = 4.1$$

A.15 Actual Problems

Let's look at the last four problems in the previous Section A.14, "Multiplication and Division," as they might be encountered by an operator.

1. A rectangular sedimentation basin treats a flow of 1.4 MGD. The volume is 15,000 cubic feet. Estimate the detention time.

Known		Unknown
Basin Volume, cu ft	= 15,000 cu ft	Detention Time, hours
Flow, MGD	= 1.4 MGD	

Calculate the detention time in hours.

$$\text{Detention Time, hrs} = \frac{(\text{Basin Volume, cu ft})(7.48\ \text{gal/cu ft})(24\ \text{hr/day})}{(\text{Flow, MGD})(1{,}000{,}000/\text{M})}$$

$$= \frac{(15{,}000\ \text{cu ft})(7.48\ \text{gal/cu ft})(24\ \text{hr/day})}{(1.4\ \text{MGD})(1{,}000{,}000/\text{M})}$$

$$= \frac{(15{,}000)(7.48)(24)}{(1.4)(1{,}000{,}000)}$$

$$= 1.9\ \text{hours}$$

2. The influent BOD to an activated sludge plant is 225 mg/*L* and the effluent BOD is 25 mg/*L*. What is the BOD removal efficiency of the plant?

---

[a] (3)(2) is the same as 3 × 2 = 6.

Known	Unknown
Influent BOD, mg/L = 225 mg/L	Plant Efficiency, %
Effluent BOD, mg/L = 25 mg/L	

Calculate the efficiency of the plant in removing BOD.

$$\text{Plant BOD Efficiency, \%} = \left(\frac{\text{In-Out}}{\text{In}}\right)(100\%)$$

$$= \left(\frac{225 \text{ mg/}L - 25 \text{ mg/}L}{225 \text{ mg/}L}\right)(100\%)$$

$$= \left(\frac{225 - 25}{225}\right)(100\%)$$

$$= 88.9\%$$

3. A chlorinator is set to feed twelve pounds of chlorine per day to a flow of 300 gallons per minute (0.432 million gallons per day). What is the chlorine dose in milligrams per liter?

Known	Unknown
Chlorinator Feed, lbs/day = 12 lbs/day	Chlorine Dose, mg/L
Flow, MGD = 0.432 MGD	

Determine the chlorine dose in milligrams per liter.

$$\text{Chlorine Dose, mg/}L = \frac{\text{Chlorinator Feed Rate, lbs/day}}{(\text{Flow, MGD})(8.34 \text{ lbs/gal})}$$

$$= \frac{12 \text{ lbs/day}}{(0.432 \text{ MGD})(8.34 \text{ lbs/gal})}$$

$$= \frac{12}{(0.432)(8.34)}$$

$$= 3.3 \text{ mg/}L$$

4. Estimate the sludge age for an activated sludge plant with a mixed liquor suspended solids (MLSS) of 1800 mg/*L* and an aeration tank volume of 0.50 MG. The flow is 2.0 MGD and primary effluent suspended solids are 110 mg/*L*.

Known	Unknown
MLSS, mg/L = 1800 mg/L	Sludge Age, days
P.E. SS, mg/L = 110 mg/L	
Tank Vol, MG = 0.50 MG	
Flow, MGD = 2.0 MGD	

Calculate the sludge age for the aeration tank in days.

$$\text{Sludge Age, days} = \frac{(\text{MLSS, mg/}L)(\text{Tank Vol, MG})(8.34 \text{ lbs/gal})}{(\text{P.E. SS, mg/}L)(\text{Flow, MGD})(8.34 \text{ lbs/gal})}$$

$$= \frac{(1800 \text{ mg/}L)(0.50 \text{ MG})(8.34 \text{ lbs/gal})}{(110 \text{ mg/}L)(2.0 \text{ MGD})(8.34 \text{ lbs/gal})}$$

$$= \frac{(1800)(0.50)(8.34)}{(110)(2.0)(8.34)}$$

$$= 4.1 \text{ days}$$

A.16 Percentage

Expressing a number in percentage is just another, and sometimes simpler, way of writing a fraction or a decimal. It can be thought of as parts per 100 parts, since the percentage is the numerator of a fraction whose denominator is always 100. Twenty-five parts per 100 parts is more easily recognized as 25/100 or 0.25. However, it is also 25%. In this case, the symbol % takes the place of the 100 in the fraction and the decimal point in the decimal fraction.

For the above example it can be seen that changing from a fraction or a decimal to percent is not a difficult procedure.

1. To change a fraction to percent, multiply by 100%.

Example: $\frac{2}{5} \times 100\% = \frac{200\%}{5} = 40\%$

Example: $\frac{5}{4} \times 100\% = \frac{500\%}{4} = 125\%$

2. To change percent to a fraction, divide by 100%.

Example: $15\% \div 100\% = 15\% \times \frac{1}{100\%} = \frac{15}{100} = \frac{3}{20}$

Example: $0.4\% \div 100\% = 0.4\% \times \frac{1}{100\%} = \frac{.4}{100} = \frac{4}{1000} = \frac{1}{250}$

In these examples note that the two percent signs cancel each other.

Following is a table comparing common fractions, decimal fractions, and percent to indicate their relationship to each other:

Common Fraction	Decimal Fraction	Percent
$\frac{285}{100}$	2.85	285%
$\frac{100}{100}$	1.0	100%
$\frac{20}{100}$	0.20	20%
$\frac{1}{100}$	0.01	1%
$\frac{1}{1000}$	0.001	0.1%
$\frac{1}{1{,}000{,}000}$	0.000001	0.0001%

A.17 Sample Problems Involving Percent

Problems involving percent are usually not complicated since their solution consists of only one or two steps. The principal error made is usually a misplaced decimal point. The most common type percentage problem is finding:

1. *WHAT PERCENT ONE NUMBER IS OF ANOTHER*

In this case, the problem is simply one of reading carefully to determine the correct fraction and then converting to a percentage.

Example: What percent is 20 of 25?

$$\frac{20}{25} = \frac{4}{5} = 0.8$$

$$0.8 \times 100\% = 80\%$$

Example: Four is what percent of 14?

$$\frac{4}{14} = 0.2857$$

$$0.2857 \times 100\% = 28.57\%$$

Example: The input or brake horsepower to a pump is 20 horsepower. Output or water horsepower is 15 hp. What is the efficiency of the pump?

$$\text{Efficiency, \%} = \frac{(\text{Output})(100\%)}{\text{Input}} = \frac{(\text{Water hp})(100\%)}{\text{Brake hp}}$$

$$= \frac{(15 \text{ hp})(100\%)}{20 \text{ hp}}$$

$$= 75\%$$

2. *PERCENT OF A GIVEN NUMBER*

In this case the percent is expressed as a decimal, and the two numbers are multiplied together.

Example: Find 7% of 32.

$$\frac{7\%}{100\%} \times 32 = 2.24$$

Example: Find 90% of 5.

$$\frac{90\%}{100\%} \times 5 = 4.5$$

Example: What is the weight of dry solids in a ton (2000 lbs) of wastewater sludge containing 5% solids and 95% water?

NOTE: 5% solids means there are 5 lbs of dry solids for every 100 lbs of wet sludge.

Therefore

$$2000 \text{ lbs} \times \frac{5\%}{100\%} = 100 \text{ lbs of solids}$$

A variation of the preceding problem is:

3. *FINDING A NUMBER WHEN A GIVEN PERCENT OF IT IS KNOWN*

Since this problem is similar to the previous problem, the solution is to convert to a decimal and divide by the decimal.

Example: If 5% of a number is 52, what is the number?

$$\left(\frac{100\%}{5\%}\right)(52) = 1040$$

A check calculation may now be performed — what is 5% of 1040?

$$\left(\frac{5\%}{100\%}\right)(1040) = 52 \text{ (Check)}$$

Example: 16 is 80% of what amount?

$$\left(\frac{100\%}{80\%}\right)(16) = 20$$

Example: An electric motor for a pump is 90% efficient. If the motor must deliver 720 watts, how many watts are required to run the motor?

$$\text{Efficiency, \%} = \frac{(\text{Output})(100\%)}{\text{Input}}$$

$$90\% = \frac{(720 \text{ watts})(100\%)}{\text{Input, watts}}$$

$$\text{Input, Watts} = \frac{(720 \text{ watts})(100\%)}{90\%}$$

$$= 800 \text{ watts}$$

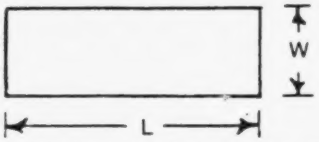
A.2 AREAS

A.20 Units

Areas are measured in two dimensions or in square units. In the English system of measurement the most common units are square inches, square feet, square yards, and square miles. In the metric system the units are square millimeters, square centimeters, square meters, and square kilometers.

A.21 Rectangle

The area of a rectangle is equal to its length (L) multiplied by its width (W).



A = L × W

Example: Find the area of a rectangle if the length is 5 feet and the width is 3.5 feet.

$$\begin{aligned} \text{Area, sq ft} &= \text{Length, ft} \times \text{Width, ft} \\ &= 5 \text{ ft} \times 3.5 \text{ ft} \\ &= 17.5 \text{ ft}^2 \\ &= 17.5 \text{ sq ft} \end{aligned}$$

Example: The surface area of a loading dock is 330 square feet. One side measures 15 feet. How long is the other side?

$$A = L \times W$$

$$330 \text{ sq ft} = L \text{ ft} \times 15 \text{ ft}$$

$$\frac{L \text{ ft} \times 15 \text{ ft}}{15 \text{ ft}} = \frac{330 \text{ ft}^2}{15 \text{ ft}} \quad \text{Divide both sides of equation by 15 ft.}$$

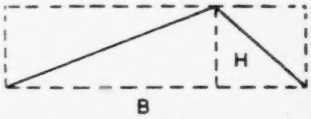
$$L \text{ ft} = \frac{330 \text{ ft}^2}{15 \text{ ft}}$$

$$= 22 \text{ ft}$$

A.22 Triangle

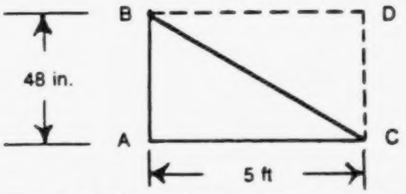
The area of a triangle is equal to one half the base multiplied by the height. This is true for any triangle.

A = ½ B × H



NOTE: The area of *ANY* triangle is equal to ½ the area of the rectangle that can be drawn around it. The area of the rectangle is B × H. The area of the triangle is ½ B × H.

Example: Find the area of triangle ABC.



The first step in the solution is to make all the units the same. In this case, it is easier to change inches to feet.

$$48 \cancel{\text{in}} = 48 \text{ in} \times \frac{1 \text{ ft}}{12 \cancel{\text{in}}} = \frac{48}{12} \text{ ft} = 4 \text{ ft}$$

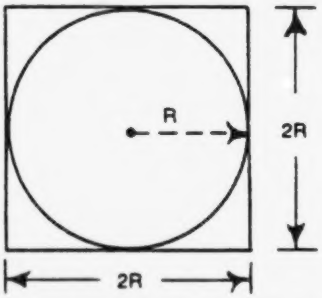
NOTE: All conversions should be calculated in the above manner. Since 1 ft/12 in is equal to unity, or one, multiplying by this factor changes the form of the answer but not its value.

$$\begin{aligned}\text{Area, sq ft} &= \tfrac{1}{2}\,(\text{Base, ft})(\text{Height, ft})\\ &= \tfrac{1}{2} \times 5\text{ ft} \times 4\text{ ft}\\ &= \frac{20}{2}\text{ ft}^2\\ &= 10\text{ sq ft}\end{aligned}$$

NOTE: Triangle ABC is one half the area of rectangle ABCD. The triangle is a special form called a *RIGHT TRIANGLE* since it contains a 90° angle at point A.

A.23 Circle

A square with sides of 2R can be drawn around a circle with a radius of R.



The area of the square is: $A = 2R \times 2R = 4R^2$.

It has been found that the area of any circle inscribed within a square is slightly more than ¾ of the area of the square. More precisely, the area of the preceding circle is:

$$A\text{ circle} = 3\frac{1}{7}R^2 = 3.14\,R^2$$

The formula for the area of a circle is usually written:

$$\boxed{A = \pi R^2}$$

The Greek letter π (pronounced pie) merely substitutes for the value 3.1416.

Since the diameter of any circle is equal to twice the radius, the formula for the area of a circle can be rewritten as follows:

$$A=\pi R^2=\pi\times R\times R=\pi\times\frac{D}{2}\times\frac{D}{2}=\frac{\pi D^2}{4}=\frac{3.14}{4}D^2=\boxed{0.785\,D^2}$$

The type of problem and the magnitude of the numbers in a problem will determine which of the two formulas will provide a simpler solution. All of these formulas will give the same results if you use the same number of digits to the right of the decimal point.

Example: What is the area of a circle with a diameter of 20 centimeters?

In this case, the formula using a radius is more convenient since it takes advantage of multiplying by 10.

$$\begin{aligned}\text{Area, sq cm} &= \pi\,(\text{R, cm})^2\\ &= 3.14 \times 10\text{ cm} \times 10\text{ cm}\\ &= 314\text{ sq cm}\end{aligned}$$

Example: What is the area of a gasoline storage tank with a 5-foot radius?

In this case, the formula using diameter is more convenient.

$$\begin{aligned}\text{Area, sq ft} &= 0.785\,(\text{Diameter, ft})^2\\ &= 0.785 \times 10\text{ ft} \times 10\text{ ft}\\ &= 7850\text{ sq ft}\end{aligned}$$

Occasionally the operator may be confronted with a problem giving the area and requesting the radius or diameter. This presents the special problem of finding the square root of the number.

Example: The surface area of a garden inside a traffic circle is approximately 5000 square feet. What is the diameter?

$A = 0.785\,D^2$, or

Area, sq ft = 0.785 (Diameter, ft)^2

5000 sq ft = $0.785\,D^2$ — To solve, substitute given values in equation.

$\frac{0.785\,D^2}{0.785} = \frac{5000\text{ sq ft}}{0.785}$— Divide both sides by 0.785 to find D^2

$$\begin{aligned}D^2 &= \frac{5000\text{ sq ft}}{0.785}\\ &= 6369\text{ sq ft. Therefore,}\end{aligned}$$

D = square root of 6369 sq ft, or

Diameter, ft = $\sqrt{6369\text{ sq ft}}$.

Punch the $\sqrt{}$ sign on your calculator and get D = 79.8 ft.

Sometimes it is easier to use a trial and error method of finding square roots. Since 80 × 80 = 6400, we know the answer is close to 80 feet.

Try 79 × 79 = 6241

Try 79.5 × 79.5 = 6320.25

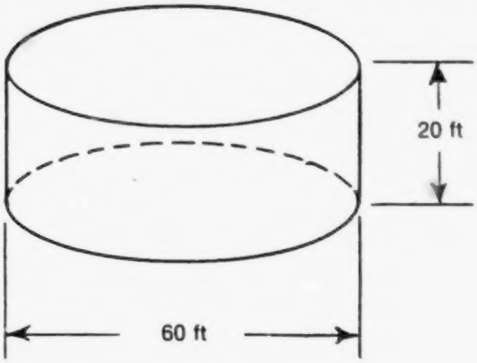
Try 79.8 × 79.8 = 6368.04

The diameter is 79.8 ft, or approximately 80 feet.

A.24 Cylinder

With the formulas presented thus far, it would be a simple matter to find the number of square feet in a room that was to be painted. The length of each wall would be added together and then multiplied by the height of the wall. This would give the surface area of the walls (minus any area for doors and windows). The ceiling area would be found by multiplying length times width and the result added to the wall area gives the total area.

The surface area of a circular cylinder, however, has not been discussed. If we wanted to know how many square feet of surface area are in a tank with a diameter of 60 feet and a height of 20 feet, we could start with the top and bottom.



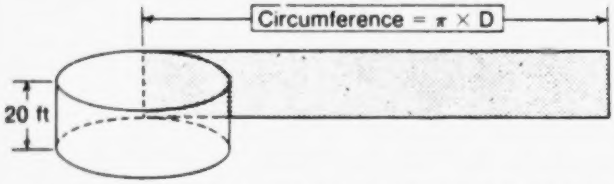
The area of the top and bottom ends are both $\pi \times R^2$

Area, sq ft $= 2 \text{ ends } (\pi)(\text{Radius, ft})^2$

$= 2 \times \pi \times (30 \text{ ft})^2$

$= 5652$ sq ft

The surface area of the wall must now be calculated. If we made a vertical cut in the wall and unrolled it, the straightened wall would be the same length as the circumference of the floor and ceiling.



This length has been found to always be $\pi \times D$. In the case of the tank, the length of the wall would be:

Length, ft $= (\pi)$ (Diameter, ft)

$= 3.14 \times 60$ ft

$= 188.4$ ft

Area would be:

A_w sq ft $=$ Length, ft $\times$ Height, ft

$= 188.4 \text{ ft} \times 20 \text{ ft}$

$= 3768$ sq ft

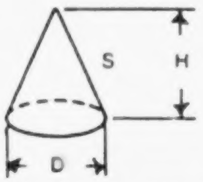
Outside Surface Area to Paint, sq ft $=$ Area of top and bottom, sq ft $+$ Area of wall, sq ft

$= 5652 \text{ sq ft} + 3768 \text{ sq ft}$

$= 9420$ sq ft

A container has inside and outside surfaces and you may need to paint both of them.

A.25 Cone



The lateral area of a cone is equal to ½ of the slant height (S) multiplied by the circumference of the base.

$$\boxed{A_L = \tfrac{1}{2} S \times \pi \times D = \pi \times S \times R}$$

In this case the slant height is not given, it may be calculated by:

$S = \sqrt{R^2 + H^2}$

Example: Find the entire outside area of a cone with a diameter of 30 inches and a height of 20 inches.

Slant Height, in $= \sqrt{(\text{Radius, in})^2 + (\text{Height, in})^2}$

$= \sqrt{(15 \text{ in})^2 + (20 \text{ in})^2}$

$= \sqrt{225 \text{ in}^2 + 400 \text{ in}^2}$

$= \sqrt{625 \text{ in}^2}$

$= 25$ in

Area of Cone, sq in $= \pi$ (Slant Height, in)(Radius, in)

$= 3.14 \times 25 \text{ in} \times 15 \text{ in}$

$= 1177.5$ sq in

Since the entire area was asked for, the area of the base must be added.

Area, sq in $= 0.785 (\text{Diameter, in})^2$

$= 0.785 \times 30 \text{ in} \times 30 \text{ in}$

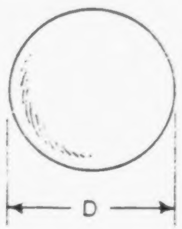
$= 706.5$ sq in

$=$ Area of Cone, sq in $+$ Area of Bottom, sq in

Total Area, sq in $= 1177.5 \text{ sq. in} + 706.5 \text{ sq in}$

$= 1884$ sq in

A.26 Sphere



The surface area of a sphere or ball is equal to π multiplied by the diameter squared.

$$\boxed{A_S = \pi D^2}$$

If the radius is used, the formula becomes:

$$A_S = \pi D^2 = \pi \times 2R \times 2R = 4\pi R^2$$

Example: What is the surface area of a sphere-shaped water tank 20 feet in diameter?

Area, sq ft $= \pi (\text{Diameter, ft})^2$

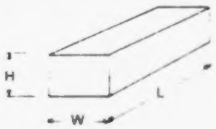
$= 3.14 \times 20 \text{ ft} \times 20 \text{ ft}$

$= 1256$ sq ft

A.3 VOLUMES

A.30 Rectangle

Volumes are measured in three dimensions or in cubic units. To calculate the volume of a rectangle, the area of the base is calculated in square units and then multipled by the height. The formula then becomes:



$$\boxed{V = L \times W \times H}$$

Example: The length of a box is two feet, the width is 15 inches, and the height is 18 inches. Find its volume.

Volume, cu ft = Length, ft × Width, ft × Height, ft

$$= 2\text{ ft} \times \frac{15\text{ in}}{12\text{ in/ft}} \times \frac{18\text{ in}}{12\text{ in/ft}}$$

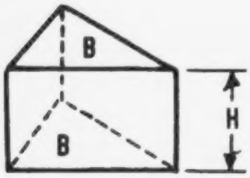
$$= 2\text{ ft} \times 1.25\text{ ft} \times 1.5\text{ ft}$$

$$= 3.75\text{ cu ft}$$

A.31 Prism

The same general rule that applies to the volume of a rectangle also applies to a prism.

$$\boxed{\text{Volume} = \text{Area of Base} \times \text{Height}}$$



Example: Find the volume of a prism with a base area of 10 square feet and a height of 5 feet. (Note that the base of a prism is triangular in shape)

Volume, cu ft = Area of Base, sq ft × Height, ft

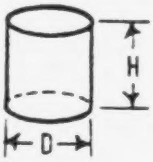
$$= 10\text{ sq ft} \times 5\text{ ft}$$

$$= 50\text{ cu ft}$$

A.32 Cylinder

The volume of a cylinder is equal to the area of the base multiplied by the height.

$$\boxed{V = \pi R^2 \times H = 0.785\ D^2 \times H}$$



Example: A 24-inch sewer is 360 feet long. Find the volume. Use length instead of height.

Volume, cu ft = (0.785)(Diameter, ft)^2(Length, ft)

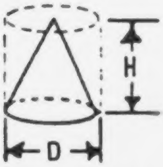
$$= (0.785)(2\text{ ft})^2(360\text{ ft})$$

$$= 1131\text{ cu ft}$$

A.33 Cone

The volume of a cone is equal to ⅓ the volume of a circular cylinder of the same height and diameter.

$$\boxed{V = \frac{\pi}{3} R^2 \times H}$$



Example: Calculate the volume in a cone if the depth or height is 4 feet and the radius is 50 feet.

$$\text{Volume, cu ft} = \frac{\pi}{3} \times (\text{Radius})^2 \times \text{Height, ft}$$

$$= \frac{\pi}{3} \times 50\text{ ft} \times 50\text{ ft} \times 4\text{ ft}$$

$$= 10{,}500\text{ cu ft}$$

A.34 Sphere

The volume of a sphere is equal to π/6 times the diameter cubed.

$$V = \frac{\pi}{6} \times D^3$$

Example: How much gas can be stored in a sphere with a diameter of 12 feet? (Assume atmospheric pressure.)

$$\text{Volume, cu ft} = \frac{\pi}{6} \times (\text{Diameter, ft})^3$$

$$= \frac{\pi}{\cancel{6}} \times \overset{2}{\cancel{12}}\text{ ft} \times 12\text{ ft} \times 12\text{ ft}$$

$$= 905\text{ cubic feet}$$

A.4 METRIC SYSTEM

The two most common systems of weights and measures are the English system and the Metric system. Of these two, the Metric system is more popular with most of the nations of the world. The reason for this is that the Metric system is based on a system of tens and is therefore easier to remember and easier to use than the English system. Even though the basic system in the United States is the English system, the scientific community uses the Metric system almost exclusively. Many organizations have urged, for good reason, that the United States switch to the Metric system. Today the Metric system is gradually becoming the standard system of measurement in the United States.

As the United States changes from the English to the Metric system, some confusion and controversy has developed. For example, which is the correct spelling of the following words:

1. Liter or litre?
2. Meter or metre?

The U.S. National Bureau of Standards, the Water Pollution Control Federation, and the American Water Works Association use litre and metre. The U.S. Government uses liter and meter and accepts no deviations. Some people argue that METRE should be used to measure LENGTH and that METER should be used to measure FLOW RATES (like a water or electric meter). Liter and Meter are used in this manual because this is most consistent with spelling in the United States.

One of the most frequent arguments heard against the U.S. switching to the Metric system was that the costs of switching manufacturing processes would be excessive. Pipe manufacturers have agreed upon the use of a "soft" metric conversion system during the conversion to the Metric system. Past practice in the U.S. has identified some types of pipe by external (outside) diameter while other types are classified by nominal (existing only in name, not real or actual) bore. This means that a six-inch pipe does not have a six-inch inside diameter. With the strict or "hard" metric system, a six-inch pipe would be a 152.4 mm (6 in × 25.4 mm/in) pipe. In the "soft" metric system a six-inch pipe is a 150 mm (6 in × 25 mm/in) pipe. Typical customary and "soft" metric pipe-size designations are shown below:

PIPE-SIZE DESIGNATIONS

Customary, in	2	4	6	8	10	12	15	18
"Soft" Metric, mm	50	100	150	200	250	300	375	450
Customary, in	24	30	36	42	48	60	72	84
"Soft" Metric, mm	600	750	900	1050	1200	1500	1800	2100

In order to study the Metric system, you must know the meanings of the terminology used. Following is a list of Greek and Latin prefixes used in the Metric system.

PREFIXES USED IN THE METRIC SYSTEM

Prefixes	Symbol	Meaning
Micro	μ	1/1 000 000 or 0.000 001
Milli	m	1/1000 or 0.001
Centi	c	1/100 or 0.01
Deci	d	1/10 or 0.1
Unit		1
Deka	da	10
Hecto	h	100
Kilo	k	1000
Mega	M	1 000 000

A.40 Measures of Length

The basic measure of length is the meter.

1 kilometer (km) = 1000 meters (m)
1 meter (m) = 100 centimeters (cm)
1 centimeter (cm) = 10 millimeters (mm)

Kilometers are usually used in place of miles, meters are used in place of feet and yards, centimeters are used in place of inches and millimeters are used for inches and fractions of an inch.

LENGTH EQUIVALENTS

1 kilometer	= 0.621 mile	1 mile	= 1.61 kilometers
1 meter	= 3.28 feet	1 foot	= 0.305 meter
1 meter	= 39.37 inches	1 inch	= 0.0254 meter
1 centimeter	= 0.3937 inch	1 inch	= 2.54 centimeters
1 millimeter	= 0.0394 inch	1 inch	= 25.4 millimeters

NOTE: The above equivalents are reciprocals. If one equivalent is given, the reverse can be obtained by division. For instance, if one meter equals 3.28 feet, one foot equals 1/3.28 meter, or 0.305 meter.

A.41 Measures of Capacity or Volume

The basic measure of capacity in the Metric system is the liter. For measurement of large quantities the cubic meter is sometimes used.

1 kiloliter (k*L*) = 1000 liters (*L*) = 1 cu meter (m^3)

1 liter (*L*) = 1000 milliliters (m*L*)

Kiloliters, or cubic meters, are used to measure capacity of large storage tanks or reservoirs in place of cubic feet or gallons. Liters are used in place of gallons or quarts. Milliliters are used in place of quarts, pints, or ounces.

CAPACITY EQUIVALENTS

1 kiloliter	= 264.2 gallons	1 gallon	= 0.003785 kiloliter
1 liter	= 1.057 quarts	1 quart	= 0.946 liter
1 liter	= 0.2642 gallons	1 gallon	= 3.785 liters
1 milliliter	= 0.0353 ounce	1 ounce	= 28.35 milliliters

A.42 Measures of Weight

The basic unit of weight in the Metric system is the gram. One cubic centimeter of water at maximum density weighs one gram, and thus there is a direct, simple relation between volume of water and weight in the Metric system.

1 kilogram (kg) = 1000 grams (gm)
1 gram (gm) = 1000 milligrams (mg)
1 milligram (mg) = 1000 micrograms (μg)

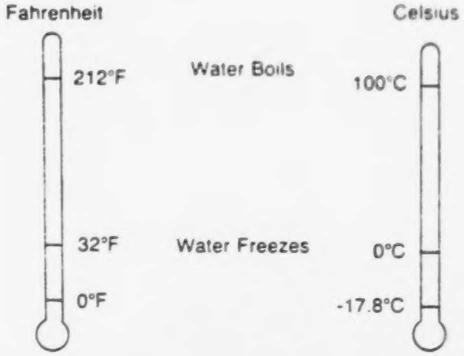
Grams are usually used in place of ounces, and kilograms are used in place of pounds.

WEIGHT EQUIVALENTS

1 kilogram	= 2.205 pounds	1 pound	= 0.4536 kilogram
1 gram	= 0.0022 pound	1 pound	= 453.6 grams
1 gram	= 0.0353 ounce	1 ounce	= 28.35 grams
1 gram	= 15.43 grains	1 grain	= 0.0648 gram

A.43 Temperature

Just as the operator should become familiar with the Metric system, you should also become familiar with the centigrade (Celsius) scale for measuring temperature. There is nothing magical about the centigrade scale — it is simply a different size than the Fahrenheit scale. The two scales compare as follows:



The two scales are related in the following manner:

$$\boxed{\begin{aligned}\text{Fahrenheit} &= (°C \times 9/5) + 32° \\ \text{Celsius} &= (°F - 32°) \times 5/9\end{aligned}}$$

Example: Convert 20° Celsius to Fahrenheit.

$$F = (°C \times 9/5) + 32°$$
$$F = (20° \times 9/5) + 32°$$
$$F = \frac{180°}{5} + 32°$$
$$= 36° + 32°$$
$$= 68°F$$

Example: Convert −10°C to °F.

$$F = (-10° \times 9/5) + 32°$$
$$F = -90°/5 + 32°$$
$$= -18° + 32°$$
$$= 14°F$$

Example: Convert −13°F to °C.

$$C = (^\circ F - 32^\circ) \times \frac{5}{9}$$

$$C = (-13^\circ - 32^\circ) \times \frac{5}{9}$$

$$= -45^\circ \times \frac{5}{9}$$

$$= -5^\circ \times 5$$

$$= -25^\circ C$$

A.44 Milligrams per Liter

Milligrams per liter (mg/*L*) is a unit of measurement used in laboratory and scientific work to indicate very small concentrations of dilutions. Since water contains small concentrations of dissolved substances and solids, and since small amounts of chemical compounds are sometimes used in water treatment processes, the term milligrams per liter is also common in treatment plants. It is a weight/volume relationship.

As previously discussed:

1000 liters = 1 cubic meter = 1,000,000 cubic centimeters.

Therefore

1 liter = 1000 cubic centimeters

Since one cubic centimeter of water weighs one gram.

1 liter of water = 1000 grams or 1,000,000 milligrams

$$\boxed{\frac{1 \text{ milligram}}{\text{liter}} = \frac{1 \text{ milligram}}{1{,}000{,}000 \text{ milligrams}} = \frac{1 \text{ part}}{\text{million parts}} = \text{1 part per million (ppm)}}$$

Milligrams per liter and parts per million (parts) may be used interchangeably as long as the liquid density is 1.0 gm/cu cm or 62.43 lb/cu ft. A concentration of 1 milligram/liter (mg/*L*) or 1 ppm means that there is 1 part of substance by weight for every 1 million parts of water. A concentration of 10 mg/*L* would mean 10 parts of substance per million parts of water.

To get an idea of how small 1 mg/*L* is, divide the numerator and denominator of the fraction by 10,000. This, of course, does not change its value since, 10,000 ÷ 10,000 is equal to one.

$$\boxed{1\,\frac{\text{mg}}{L} = \frac{1 \text{ mg}}{1{,}000{,}000 \text{ mg}} = \frac{1/10{,}000 \text{ mg}}{1{,}000{,}000/10{,}000 \text{ mg}} = \frac{0.0001 \text{ mg}}{100 \text{ mg}} = 0.0001\%}$$

Therefore, 1 mg/*L* is equal to one ten-thousandth of a percent, or

1% is equal to 10,000 mg/*L*

To convert mg/*L* to %, move the decimal point four places or numbers to the left.

A.5 WEIGHT-VOLUME RELATIONS

Another factor for the operator to remember, in addition to the weight of a gallon of water, is the weight of a cubic foot of water. One cubic foot of water weighs 62.4 lbs. If these two weights are divided, it is possible to determine the number of gallons in a cubic foot.

$$\frac{62.4 \cancel{\text{pounds}}/\text{cu ft}}{8.34 \cancel{\text{pounds}}/\text{gal}} = 7.48 \text{ gal/cu ft}$$

Thus we have another very important relationship to commit to memory.

$$\boxed{8.34 \text{ lb/gal} \times 7.48 \text{ gal/cu ft} = 62.4 \text{ lb/cu ft}}$$

It is only necessary to remember two of the above items since the third may be found by calculation. For most problems, 8⅓ lbs/gal and 7½ gal/cu ft will provide sufficient accuracy.

Example: Change 1000 cu ft of water to gallons.

1000 cu ft × 7.48 gal/cu ft = 7480 gallons

Example: What is the weight of three cubic feet of water?

62.4 lb/cu ft × 3 cu ft = 187.2 lbs

Example: The net weight of a tank of water is 750 lbs. How many gallons does it contain?

$$\frac{750 \cancel{\text{lb}}}{8.34 \cancel{\text{lb}}/\text{gal}} = 90 \text{ gals}$$

A.6 FORCE, PRESSURE, AND HEAD

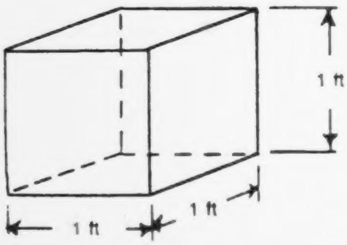
In order to study the forces and pressures involved in fluid flow, it is first necessary to define the terms used.

FORCE:	The push exerted by water on any surface being used to confine it. Force is usually expressed in pounds, tons, grams, or kilograms.
PRESSURE:	The force per unit area. Pressure can be expressed in many ways, but the most common term is pounds per square inch (psi).
HEAD:	Vertical distance from the water surface to a reference point below the surface. Usually expressed in feet or meters.

An *EXAMPLE* should serve to illustrate these terms.

If water were poured into a one-foot cubical container, the *FORCE* acting on the bottom of the container would be 62.4 pounds.

The *PRESSURE* acting on the bottom would be 62.4 pounds per square foot. The area of the bottom is also 12 in × 12 in = 144 in^2. Therefore, the pressure may also be expressed as:



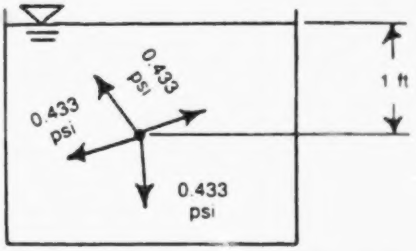
$$\text{Pressure, psi} = \frac{62.4 \text{ lb}}{\text{sq ft}} = \frac{62.4 \text{ lb/sq ft}}{144 \text{ sq in/sq ft}}$$

$$= 0.433 \text{ lb/sq in}$$

$$= 0.433 \text{ psi}$$

Since the height of the container is one foot, the *HEAD* would be one foot.

The pressure in any vessel at one foot of depth or one foot of head is 0.433 psi acting in any direction.



If the depth of water in the previous example were increased to two feet, the pressure would be:

$$p = \frac{2\ (62.4\ \text{lb})}{144\ \text{sq in}} = \frac{124.8\ \text{lb}}{144\ \text{sq in}} = 0.866\ \text{psi}$$

Therefore we can see that for every foot of head, the pressure increases by 0.433 psi. Thus, the general formula for pressure becomes:

$$\boxed{p,\ \text{psi} = 0.433\ (H,\ \text{ft})}$$

H = feet of head

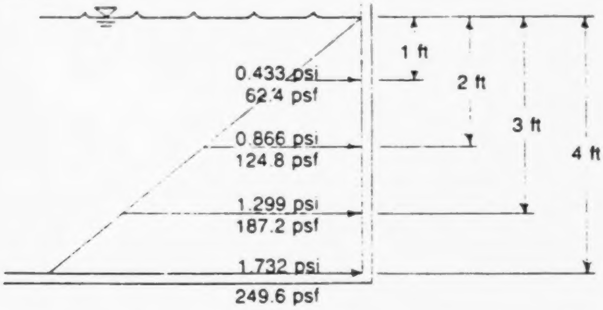
p = pounds per square *INCH* of pressure

$$\boxed{P,\ \text{lb/sq ft} = 62.4\ (H,\ \text{ft})}$$

H = feet of head

P = pounds per square *FOOT* of pressure

We can now draw a diagram of the pressure acting on the side of a tank. Assume a four-foot deep tank. The pressures shown on the tank are gage pressures. These pressures do not include the atmospheric pressure acting on the surface of the water.



$p_0 = 0.433 \times 0 = 0.0$ psi

$p_1 = 0.433 \times 1 = 0.433$ psi

$p_2 = 0.433 \times 2 = 0.866$ psi

$p_3 = 0.433 \times 3 = 1.299$ psi

$p_4 = 0.433 \times 4 = 1.732$ psi

$P_0 = 62.4 \times 0 = 0.0$ lb/sq ft

$P_1 = 62.4 \times 1 = 62.4$ lb/sq ft

$P_2 = 62.4 \times 2 = 124.8$ lb/sq ft

$P_3 = 62.4 \times 3 = 187.2$ lb/sq ft

$P_4 = 62.4 \times 4 = 249.6$ lb/sq ft

The average *PRESSURE* acting on the tank wall is 1.732 psi/2 = 0.866 psi, or 249.2 psf/2 = 124.8 psf. We divided by two to obtain the average pressure because there is zero pressure at the top and 1.732 psi pressure on the bottom of the wall.

If the wall were five feet long, the pressure would be acting over the entire 20 square foot (5 ft × 4 ft) area of the wall. The total force acting to push the wall would be:

Force, lb = (Pressure, lb/sq ft)(Area, sq ft)

= 124.8 lb/sq ft × 20 sq ft

= 2496 lbs

If the pressure in psi were used, the problem would be similar:

Force, lb = (Pressure, lb/sq in)(Area, sq in)

= 0.866 psi × 48 in × 60 in

= 2494 lb*

---

* Difference in answer due to rounding off of decimal points.

The general formula, then, for finding the total force acting on a side wall of a tank is:

$$\boxed{F = 31.2 \times H^2 \times L}$$

F = force in pounds

H = head in feet

L = length of wall in feet

31.2 = constant with units of lbs/cu ft and considers the fact that the force results from H/2 or half the depth of the water which is the average depth. The force is exerted at H/3 from the bottom.

Example: Find the force acting on a five-foot long wall in a four-foot deep tank.

Force, lb = 31.2 (Head, ft)^2 (Length, ft)

= 31.2 lb/cu ft × (4 ft)^2 × 5 ft

= 2496 lbs

Occasionally an operator is warned: *NEVER EMPTY A TANK DURING PERIODS OF HIGH GROUNDWATER.* Why? The pressure on the bottom of the tank caused by the water surrounding the tank will tend to float the tank like a cork if the upward force of the water is greater than the weight of the tank.

$$\boxed{F = 62.4 \times H \times A}$$

F = upward force in pounds

H = head of water on tank bottom in feet

A = area of bottom of tank in square feet

62.4 = a constant with units of lbs/cu ft

This formula is approximately true if the tank doesn't crack, leak, or start to float.

Example: Find the upward force on the bottom of an empty tank caused by a groundwater depth of 8 feet above the tank bottom. The tank is 20 ft wide and 40 ft long.

Force, lb = 62.4 (Head, ft)(Area, sq ft)

= 62.4 lb/cu ft × 8 ft × 20 ft × 40 ft

= 399,400 lb

A.7 VELOCITY AND FLOW RATE

A.70 Velocity

The velocity of a particle or substance is the speed at which it is moving. It is expressed by indicating the length of travel and how long it takes to cover the distance. Velocity can be expressed in almost any distance and time units. For instance, a car may be traveling at a rate of 280 miles per five hours. However, it is normal to express the distance traveled per unit time. The above example would then become:

$$\text{Velocity, mi/hr} = \frac{280\ \text{miles}}{5\ \text{hours}}$$

= 56 miles/hour

The velocity of water in a channel, pipe, or other conduit can be expressed in the same way. If the particle of water travels 600 feet in five minutes, the velocity is:

$$\text{Velocity, ft/min} = \frac{\text{distance, ft}}{\text{time, minutes}}$$

$$= \frac{600 \text{ ft}}{5 \text{ min}}$$

$$= 120 \text{ ft/min}$$

If you wish to express the velocity in feet per second, multiply by 1 min/60 seconds.

NOTE: $\frac{1 \text{ minute}}{60 \text{ seconds}}$ is like $\frac{1}{1}$ and does not change the relative value of the answer. It only changes the form of the answer.

$$\text{Velocity, ft/sec} = (\text{Velocity, ft/min})(1 \text{ min/60 sec})$$

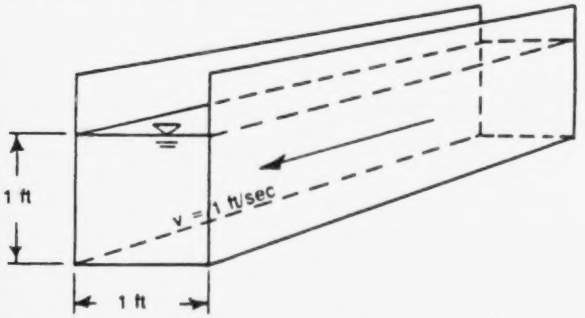
$$= \frac{120 \text{ ft}}{\cancel{\text{min}}} \times \frac{1 \cancel{\text{min}}}{60 \text{ sec}}$$

$$= \frac{120 \text{ ft}}{60 \text{ sec}}$$

$$= 2 \text{ ft/sec}$$

A.71 Flow Rate

If water in a one-foot wide channel is one foot deep, then the cross sectional area of the channel is 1 ft × 1 ft = 1 sq ft.



If the velocity in this channel is 1 ft per second, then each second a body of water 1 sq ft in area and 1 ft long will pass a given point. The volume of this body of water would be 1 cubic foot. Since one cubic foot of water would pass by every second, the flow rate would be equal to 1 cubic foot per second, or 1 cfs.

To obtain the flow rate in the above example the velocity was multiplied by the cross sectional area. This is another important general formula.

$\boxed{Q = V \times A}$

Q = flow rate, cfs or cu ft/sec

V = velocity, ft/sec

A = area, sq ft

Example: A rectangular channel 3 feet wide contains water 2 feet deep and flowing at a velocity of 1.5 feet per second. What is the flow rate in cfs?

$$Q = V \times A$$

$$\text{Flow rate, cfs} = \text{Velocity, ft/sec} \times \text{Area, sq ft}$$

$$= 1.5 \text{ ft/sec} \times 3 \text{ ft} \times 2 \text{ ft}$$

$$= 9 \text{ cu ft/sec}$$

Example: Flow in a 2.5 foot wide channel is 1.4 ft deep and measures 11.2 cfs. What is the average velocity?

In this problem we want to find the velocity. Therefore, we must rearrange the general formula to solve for velocity.

$$V = \frac{Q}{A}$$

$$\text{Velocity, ft/sec} = \frac{\text{Flow Rate, cu ft/sec}}{\text{Area, sq ft}}$$

$$= \frac{11.2 \text{ cu ft/sec}}{2.5 \text{ ft} \times 1.4 \text{ ft}}$$

$$= \frac{11.2 \text{ ft/sec}}{3.5}$$

$$= 3.2 \text{ ft/sec}$$

Example: Flow in an 8-inch pipe is 500 GPM. What is the average velocity?

$$\text{Area, sq ft} = 0.785 (\text{Diameter, ft})^2$$

$$= 0.785 (8/12 \text{ ft})^2$$

$$= 0.785 (2/3 \text{ ft})^2$$

$$= 0.785 (2/3 \text{ ft})(2/3 \text{ ft})$$

$$= 0.785 (4/9 \text{ ft}^2)$$

$$= 0.35 \text{ sq ft}$$

$$\text{Flow, cfs} = \text{Flow, gal/min} \times \frac{\text{cu ft}}{7.48 \text{ gal}} \times \frac{1 \text{ min}}{60 \text{ sec}}$$

$$= \frac{500 \text{ gal}}{\text{min}} \times \frac{\text{cu ft}}{7.48 \text{ gal}} \times \frac{1 \text{ min}}{60 \text{ sec}}$$

$$= \frac{500 \text{ cu ft}}{448.8 \text{ sec}}$$

$$= 1.114 \text{ cfs}$$

$$\text{Velocity, ft/sec} = \frac{\text{Flow, cu ft/sec}}{\text{Area, sq ft}}$$

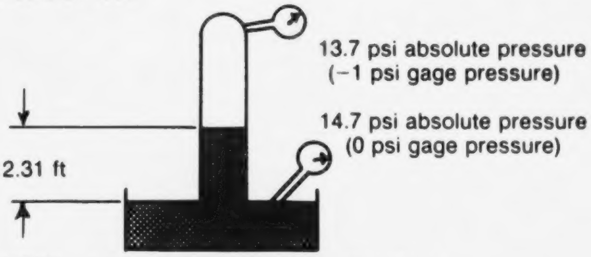
$$= \frac{1.114 \text{ ft}^3\text{/sec}}{0.35 \text{ ft}^2}$$

$$= 3.18 \text{ ft/sec}$$

A.8 PUMPS

A.80 Pressure

Atmospheric pressure at sea level is approximately 14.7 psi. This pressure acts in all directions and on all objects. If a tube is placed upside down in a basin of water and a 1 psi partial vacuum is drawn on the tube, the water in the tube will rise 2.31 feet.



NOTE: 1 ft of water = 0.433 psi; therefore,

$$1 \text{ psi} = \frac{1}{0.433} \text{ ft} = 2.31 \text{ ft of water}$$

The action of the partial vacuum is what gets water out of a sump or well and up to a pump. It is not sucked up, but it is pushed up by atmospheric pressure on the water surface in the sump. If a complete vacuum could be drawn, the water would rise 2.31 × 14.7 = 33.9 feet; but this is impossible to achieve. The practical limit of the suction lift of a positive displacement pump is about 22 feet, and that of a centrifugal pump is 15 feet.

A.81 Work

Work can be expressed as lifting a weight a certain vertical distance. It is usually defined in terms of foot-pounds.

Example: A 165-pound man runs up a flight of stairs 20 feet high. How much work did he do?

$$\begin{aligned}\text{Work, ft-lb} &= \text{Weight, lb} \times \text{Height, ft}\\ &= 165 \text{ lb} \times 20 \text{ ft}\\ &= 3300 \text{ ft-lb}\end{aligned}$$

A.82 Power

Power is a rate of doing work and is usually expressed in foot-pounds per minute.

Example: If the man in the above example runs up the stairs in three seconds, how much power has he exerted?

$$\begin{aligned}\text{Power, ft-lbs/sec} &= \frac{\text{Work, ft-lb}}{\text{Time, sec}}\\ &= \frac{3300 \text{ ft-lbs}}{3\ \cancel{\text{sec}}} \times \frac{60\ \cancel{\text{sec}}}{\text{minute}}\\ &= 66{,}000 \text{ ft-lb/min}\end{aligned}$$

A.83 Horsepower

Horsepower is also a unit of power. One horsepower is defined as 33,000 ft-lbs per minute or 746 watts.

Example: How much horsepower has the man in the previous example exerted as he climbs the stairs?

$$\begin{aligned}\text{Horsepower, HP} &= (\text{Power, ft-lb/min})\left(\frac{\text{HP}}{33{,}000 \text{ ft-lb/min}}\right)\\ &= 66{,}000 \text{ ft-lb/min} \times \frac{\text{Horsepower}}{33{,}000 \text{ ft-lb/min}}\\ &= 2 \text{ HP}\end{aligned}$$

Work is also done by lifting water. If the flow from a pump is converted to a weight of water and multiplied by the vertical distance it is lifted, the amount of work or power can be obtained.

$$\text{Horsepower, HP} = \frac{\text{Flow, gal}}{\text{min}} \times \text{Lift, ft} \times \frac{8.34 \text{ lb}}{\text{gal}} \times \frac{\text{Horsepower}}{33{,}000 \text{ ft-lb/min}}$$

Solving the above relation, the amount of horsepower necessary to lift the water is obtained. This is called water horsepower.

$$\text{Water, HP} = \frac{(\text{Flow, GPM})(\text{H, ft})}{3960^{*}}$$

1 gallon weighs 8.34 pounds and 1 horsepower is the same as 33,000 ft-lb/min.

H or Head in feet is the same as Lift in feet.

However, since pumps are not 100% efficient (they cannot transmit all the power put into them), the horsepower supplied to a pump is greater than the water horsepower. Horsepower supplied to the pump is called brake horsepower.

$$\boxed{\text{Brake, HP} = \frac{\text{Flow, GPM} \times \text{H, ft}}{3960 \times E_p}}$$

E_p = Efficiency of Pump (Usual range 50-85%, depending on type and size of pump)

Motors are also not 100% efficient; therefore, the power supplied to the motor is greater than the motor transmits.

$$\boxed{\text{Motor, HP} = \frac{\text{Flow, GPM} \times \text{H, ft}}{3960 \times E_p \times E_m}}$$

E_m = Efficiency of motor (Usual range 80-95%, depending on type and size of motor)

The above formulas have been developed for the pumping of water and wastewater which have a specific gravity of 1.0. If other liquids are to be pumped, the formulas must be multiplied by the specific gravity of the liquid.

Example: A flow of 500 GPM of water is to be pumped against a total head of 100 feet by a pump with an efficiency of 70%. What is the pump horsepower?

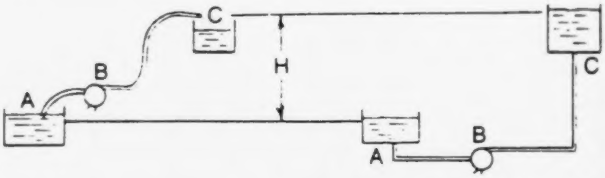
$$\begin{aligned}\text{Brake, HP} &= \frac{\text{Flow, GPM} \times \text{H, ft}}{3960 \times E_p}\\ &= \frac{500 \times 100}{3960 \times 0.70}\\ &= 18 \text{ HP}\end{aligned}$$

Example: Find the horsepower required to pump gasoline (specific gravity = 0.75) in the above problem.

$$\begin{aligned}\text{Brake, HP} &= \frac{500 \times 100 \times 0.75}{3960 \times 0.70}\\ &= 13.5 \text{ HP}\end{aligned}$$ (gasoline is lighter and requires less horsepower)

A.84 Head

Basically, the head that a pump must work against is determined by measuring the vertical distance between the two water surfaces, or the distance the water must be lifted. This is called the static head. Two typical conditions for lifting water are shown below.



If a pump were designed in the above examples to pump only against head H, the water would never reach the intended point. The reason for this is that the water encounters friction in the pipelines. Friction depends on the roughness and length of pipe, the pipe diameter, and the flow velocity. The turbulence caused at the pipe entrance (point A); the pump (point B); the pipe exit (point C); and at each elbow, bend, or transition also adds to these friction losses.

$$^{*}\ \frac{8.34 \text{ lb}}{\text{gal}} \times \frac{\text{HP}}{33{,}000 \text{ ft-lb/min}} = \frac{1}{3960}$$

Tables and charts are available in Section A.88 for calculation of these friction losses so they may be added to the measured or static head to obtain the total head. For short runs of pipe which do not have high velocities, the friction losses are generally less than 10 percent of the static head.

Example: A pump is to be located eight feet above a wet well and must lift 1.8 MGD another 50 feet to a storage reservoir. If the pump has an efficiency of 75% and the motor an efficiency of 90%, what is the cost of the power consumed if one kilowatt hour costs 4 cents?

Since we are not given the length or size of pipe and the number of elbows or bends, we will assume friction to be 10% of static head.

Static Head, ft = Suction Lift, ft + Discharge Head, ft

= 8 ft + 50 ft

= 58 ft

Friction Losses, ft = 0.1 (Static Head, ft)

= 0.1 (58 ft)

= 5.8 ft

Total Dynamic Head, ft = Static Head, ft + Friction Losses, ft

= 58 ft + 5.8 ft

= 63.8 ft

Flow, GPM $= \frac{1{,}800{,}000 \text{ gal}}{\cancel{\text{day}}} \times \frac{\cancel{\text{day}}}{24\ \cancel{\text{hr}}} \times \frac{1\ \cancel{\text{hr}}}{60 \text{ min}}$

= 1250 GPM (assuming pump runs 24 hours per day)

Motor, HP $= \frac{\text{Flow, GPM} \times \text{H, ft}}{3960 \times E_p \times E_m}$

$= \frac{1250 \times 63.8}{3960 \times 0.75 \times 0.9}$

= 30 HP

Kilowatt-hrs $= 30\ \cancel{\text{HP}} \times 24 \text{ hrs/day} \times 0.746 \text{ kw}/\cancel{\text{HP}}$*

= 537 kilowatt-hrs/day

Cost = KWH × \$0.04/KWH

= 537 × 0.04

= \$21.48/day

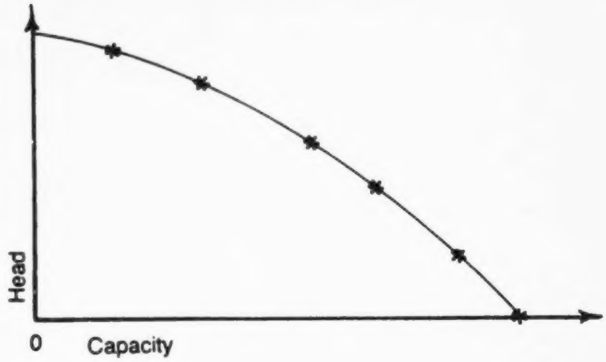
---

* See Conversion Tables — Section A.10, "Power."

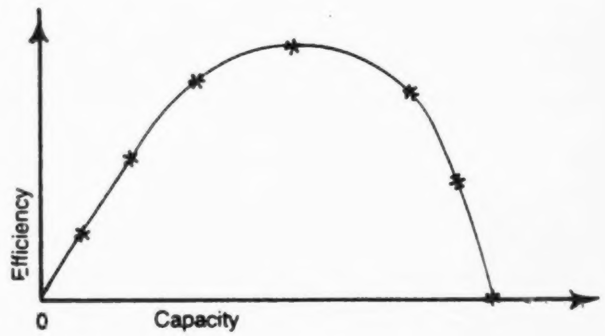
A.85 Pump Characteristics

The discharge of a centrifugal pump, unlike a positive displacement pump, can be made to vary from zero to a maximum capacity which depends on the speed, head, power, and specific impeller design. The interrelation of capacity, efficiency, head, and power is known as the characteristics of the pump.

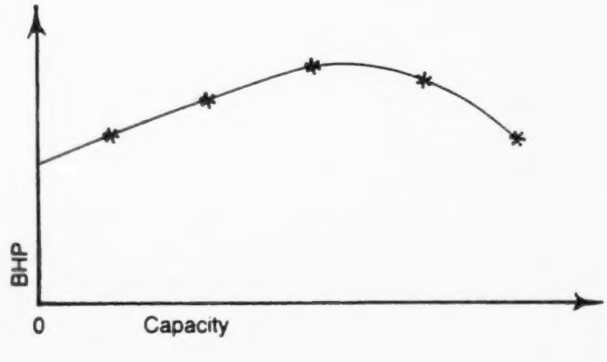
The first relation normally looked at when searching for a pump is the head vs. capacity. The head of a centrifugal pump normally rises as the capacity is reduced. If the values are plotted on a graph they appear as follows:



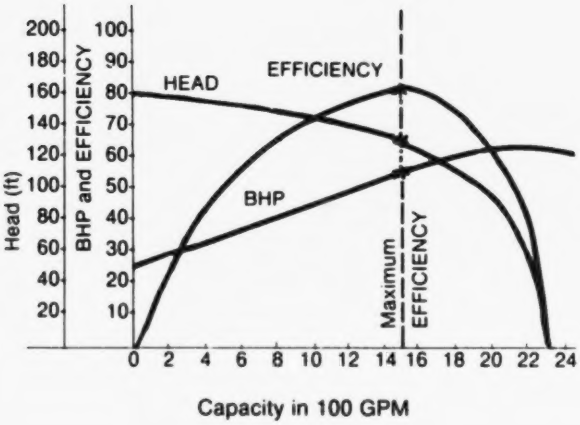
Another important characteristic is the pump efficiency. It begins from zero at no discharge, increases to a maximum, and then drops as the capacity is increased. Following is a graph of efficiency vs. capacity:



The last important characteristic is the brake horsepower or the power input to the pump. The brake horsepower usually increases with increasing capacity until it reaches a maximum, then it normally reduces slightly.



These pump characteristic curves are quite important. Pump sizes are normally picked from these curves rather than calculations. For ease of reading, the three characteristic curves are normally plotted together. A typical graph of pump characteristics is shown as follows:



The curves show that the maximum efficiency for the particular pump in question occurs at approximately 1475 GPM, a head of 132 feet, and a brake horsepower of 58. Operating at this point the pump has an efficiency of approximately 85%. This can be verified by calculation.

$$\text{BHP} = \frac{\text{Flow, GPM} \times \text{H, ft}}{3960 \times \text{E}}$$

As previously explained, a number can be written over one without changing its value:

$$\frac{\text{BHP}}{1} = \frac{\text{GPM} \times \text{H}}{3960 \times \text{E}}$$

Since the formula is now in ratio form, it can be cross multiplied.

$$\text{BHP} \times 3960 \times \text{E} = \text{GPM} \times \text{H} \times 1$$

Solving for E,

$$\text{E} = \frac{\text{GPM} \times \text{H}}{3960 \times \text{BHP}}$$

$$\text{E} = \frac{1475 \text{ GPM} \times 132 \text{ ft}}{3960 \times 58 \text{ HP}}$$

$$= 0.85 \text{ or } 85\% \text{ (Check)}$$

The preceding is only a brief description of pumps to familiarize the operator with their characteristics. The operator does not normally specify the type and size of pump needed at a plant. If a pump is needed, the operator should be able to supply the information necessary for a pump supplier to provide the best possible pump for the lowest cost. Some of the information needed includes:

1. Flow range desired
2. Head conditions
   a. Suction head or lift
   b. Pipe and fitting friction head
   c. Discharge head
3. Type of fluid pumped and temperature
4. Pump location

A.86 Evaluation of Pump Performance

1. Capacity

Sometimes it is necessary to determine the capacity of a pump. This can be accomplished by determining the time it takes a pump to fill or empty a portion of a wet well or diversion box when all inflow is blocked off.

EXAMPLE:

a. Measure the size of the wet well.

Length = 10 ft
Width = 10 ft
Depth = 5 ft (We will measure the time it takes to lower the well a distance of five feet)

Volume, cu ft = L, ft × W, ft × D, ft
= 10 ft × 10 ft × 5 ft
= 500 cu ft

b. Record time for water to drop five feet in wet well.

Time = 10 minutes 30 seconds
= 10.5 minutes

c. Calculate pumping rate or capacity.

$$\text{Pumping Rate, GPM} = \frac{\text{Volume, gallons}}{\text{Time, minutes}}$$

$$= \frac{(500 \text{ cu ft})(7.5 \text{ gal/cu ft})}{10.5 \text{ min}}$$

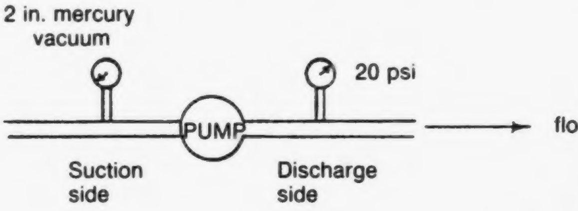
$$= \frac{3750}{10.5}$$

$$= 357 \text{ GPM}$$

If you know the total dynamic head and have the pump's performance curves, you can determine if the pump is delivering at design capacity. If not, try to determine the cause (see Chapter 15, "Maintenance"). After a pump overhaul, the pump's actual performance (flow, head, power and efficiency) should be compared with the pump manufacturer's performance curves. This procedure for calculating the rate of filling or emptying of a wet well or diversion box can be used to calibrate flow meters.

2. Efficiency

To estimate the efficiency of the pump in the previous example, the total head must be known. This head may be estimated by measuring the suction and discharge pressure. Assume these were measured as follows:



No additional information is necessary if we assume the pressure gages are at the same height and the pipe diameters are the same. Both pressure readings must be converted to feet.

$$\text{Suction Lift, ft} = 2 \text{ in Mercury} \times \frac{1.133 \text{ ft water}^*}{1 \text{ in Mercury}}$$

$$= 2.27 \text{ ft}$$

$$\text{Discharge Head, ft} = 20 \text{ psi} \times 2.31 \text{ ft/psi}^*$$

$$= 46.20 \text{ ft}$$

$$\text{Total Head, ft} = \text{Suction Lift, ft} + \text{Discharge Head, ft}$$

$$= 2.27 \text{ ft} + 46.20 \text{ ft}$$

$$= 48.47 \text{ ft}$$

---

*See Conversion Tables — Section A.10, "Pressure."

Calculate the power output of the pump or water horsepower:

$$\text{Water Horsepower, HP} = \frac{(\text{Flow GPM})(\text{Head, ft})}{3960}$$

$$= \frac{(357 \text{ GPM})(48.47 \text{ ft})}{3960}$$

$$= 4.4 \text{ HP}$$

To estimate the efficiency of the pump, measure the kilowatts drawn by the pump motor. Assume the meter indicates 8000 watts or 8 kilowatts. The manufacturer claims the electric motor is 80% efficient.

$$\text{Brake Horsepower, HP} = (\text{Power to elec. motor})(\text{motor eff.})$$

$$= \frac{(8 \text{ kw})(0.80)}{0.746 \text{ kw/HP}}$$

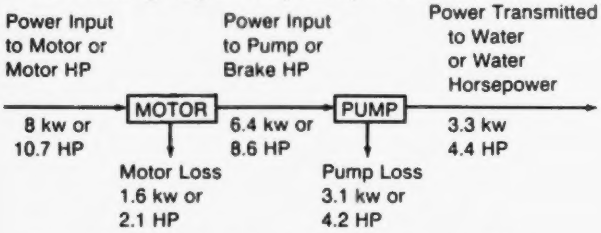
$$= 8.6 \text{ HP}$$

$$\text{Pump Efficiency, \%} = \frac{\text{Water Horsepower, HP} \times 100\%}{\text{Brake Horsepower, HP}}$$

$$= \frac{4.4 \text{ HP} \times 100\%}{8.6 \text{ HP}}$$

$$= 51\%$$

The following diagram may clarify the above problem:



Power Input to Motor or Motor HP
Power Input to Pump or Brake HP
Power Transmitted to Water or Water Horsepower
MOTOR
PUMP
8 kw or 10.7 HP
6.4 kw or 8.6 HP
3.3 kw 4.4 HP
Motor Loss 1.6 kw or 2.1 HP
Pump Loss 3.1 kw or 4.2 HP

The wire-to-water efficiency is the efficiency of the power input to produce water horsepower.

$$\text{Wire-to-Water Efficiency, \%} = \frac{\text{Water Horsepower, HP}}{\text{Power Input, HP}} \times 100\%$$

$$= \frac{4.4 \text{ HP}}{10.7 \text{ HP}} \times 100\%$$

$$= 41\%$$

A.87 Pump Speed — Performance Relationships

Changing the velocity of a centrigual pump will change its operating characteristics. If the speed of a pump is changed, the flow, head developed, and power requirements will change. The operating characteristics of the pump will change with speed approximately as follows:

$$\text{Flow, } Q_n = \left[\frac{N_n}{N_r}\right] Q_r$$

$$\text{Head, } H_n = \left[\frac{N_n}{N_r}\right]^2 H_r$$

$$\text{Power, } P_n = \left[\frac{N_n}{N_p}\right]^3 P_r$$

r = rated

n = now

N = pump speed

Actually, pump efficiency does vary with speed; therefore, these formulas are not quite correct. If speeds do not vary by more than a factor of two (if the speeds are not doubled or cut in half), the results are close enough. Other factors contributing to changes in pump characteristic curves include impeller wear and roughness in pipes.

Example: To illustrate these relationships, assume a pump has a rated capacity of 600 GPM, develops 100 ft of head, and has a power requirement of 15 HP when operating at 1500 rpm. If the efficiency remains constant, what will be the operating characteristics if the speed drops to 1200 rpm?

Calculate new flow rate or capacity:

$$\text{Flow, } Q_n = \left[\frac{N_n}{N_r}\right] Q_r$$

$$= \left[\frac{1200 \text{ rpm}}{1500 \text{ rpm}}\right] 600 \text{ GPM}$$

$$= \left[\frac{4}{5}\right] 600 \text{ GPM}$$

$$= (4)(120 \text{ GPM})$$

$$= 480 \text{ GPM}$$

Calculate new head:

$$\text{Head, } H_n = \left[\frac{N_n}{N_r}\right]^2 H_r$$

$$= \left[\frac{1200 \text{ rpm}}{1500 \text{ rpm}}\right]^2 100 \text{ ft}$$

$$= \left(\frac{4}{5}\right)^2 100 \text{ ft}$$

$$= \left(\frac{16}{25}\right)(100 \text{ ft})$$

$$= 16 (4 \text{ ft})$$

$$= 64 \text{ ft}$$

Calculate new power requirement:

$$\text{Power, } P_n = \left[\frac{N_n}{N_r}\right]^3 P_r$$

$$= \left(\frac{1200 \text{ rpm}}{1500 \text{ rpm}}\right)^3 15 \text{ HP}$$

$$= \left(\frac{4}{5}\right)^3 15 \text{ HP}$$

$$= \left(\frac{64}{125}\right) 15 \text{ HP}$$

$$= \left(\frac{64}{25}\right)(3 \text{ HP})$$

$$= 7.7 \text{ HP}$$

A.88 Friction or Energy Losses

Whenever water flows through pipes, valves and fittings, energy is lost due to pipe friction (resistance), friction in valves and fittings, and the turbulence resulting from the flowing water changing its direction. Figure A.1 can be used to convert the friction losses through valves and fittings to lengths of straight pipe that would produce the same amount of friction losses. To estimate the friction or energy losses resulting from water flowing in a pipe system, we need to know:

1. Water flow rate,
2. Pipe size or diameter and length, and
3. Number, size and type of valve fittings.

An easy way to estimate friction or energy losses is to follow the following steps:

1. Determine the flow rate;
2. Determine the diameter and length of pipe;
3. Convert all valves and fittings to equivalent lengths of straight pipe (see Figure A.1);
4. Add up total length of equivalent straight pipe; and
5. Estimate friction or energy losses by using Figure A.2. With the flow in GPM and diameter of pipe, find the friction loss per 100 feet of pipe. Multiply this value by equivalent length of straight pipe.

The procedure for using Figure A.1 is very easy. Locate the type of valve or fitting you wish to convert to an equivalent pipe length; find its diameter on the right-hand scale; and draw a straight line between these two points to locate the equivalent length of straight pipe.

Example: Estimate the friction losses in the piping system of a pump station when the flow is 1,000 GPM. The 8-inch suction line is 10 feet long and contains a 90-degree bend (long sweep elbow), a gate valve and an 8-inch by 6-inch reducer at the inlet to the pump. The 6-inch discharge line is 30 feet long and contains a check valve, a gate valve, and three 90-degree bends (medium sweep elbows):

SUCTION LINE (8-inch diameter)

Item	Equivalent Length, ft
1. Length of pipe	10
2. 90-degree bend	14
3. Gate valve	4
4. 8-inch by 6-inch reducer	17
5. Ordinary entrance	12
Total equivalent length	57 feet

Friction loss (Fig. A.2) = 1.76 ft/100 ft of pipe

DISCHARGE LINE (6-inch diameter)

Item	Equivalent Length, ft
1. Length of pipe	30
2. Check valve	38
3. Gate valve	4
4. Three 90-degree bends (3) (14)	42
Total equivalent length	114 feet

Friction loss (Fig. A.2) = 7.73 ft/100 ft of pipe

Estimate the total friction losses in pumping system for a flow of 1,000 GPM.

SUCTION

Loss = (1.76 ft/100 ft) (57 ft) = 1.0 Ft

DISCHARGE

Loss = (7.73 ft/100 ft)(114 ft) = 8.8 ft

Total friction losses, ft = 8.9 ft

A.9 STEPS IN SOLVING PROBLEMS

A.90 Identification of Problem

To solve any problem, you have to identify the problem, determine what kind of answer is needed, and collect the information needed to solve the problem. A good approach to this type of problem is to examine the problem and make a list of *KNOWN* and *UNKNOWN* information.

Example: Find the theoretical detention time in a rectangular sedimentation tank 8 feet deep, 30 feet wide, and 60 feet long when the flow is 1.4 MGD.

	Known	Unknown
Depth	= 8 ft	Detention Time, hours
Width	= 30 ft	
Length	= 60 ft	
Flow	= 1.4 MGD	

Sometimes a drawing or sketch will help to illustrate a problem and indicate the knowns, unknowns, and possibly additional information needed.

A.91 Selection of Formula

Most problems involving mathematics in wastewater treatment plant operation can be solved by selecting the proper formula, inserting the known information, and calculating the unknown. In our example, we could look in chapter 5, "Sedimentation," or in Section A.11 of this chapter, "Basic Formulas," to find a formula for calculating detention time. From Section A.11:

$$\text{Detention Time, hrs} = \frac{(\text{Tank Volume, cu ft})(7.48\ \text{gal/cu ft})(24\ \text{hr/day})}{\text{Flow, gal/day}}$$

To convert the known information to fit the terms in a formula sometimes requires extra calculations. The next step is to find the values of any terms in the formula that are not in the list of known values.

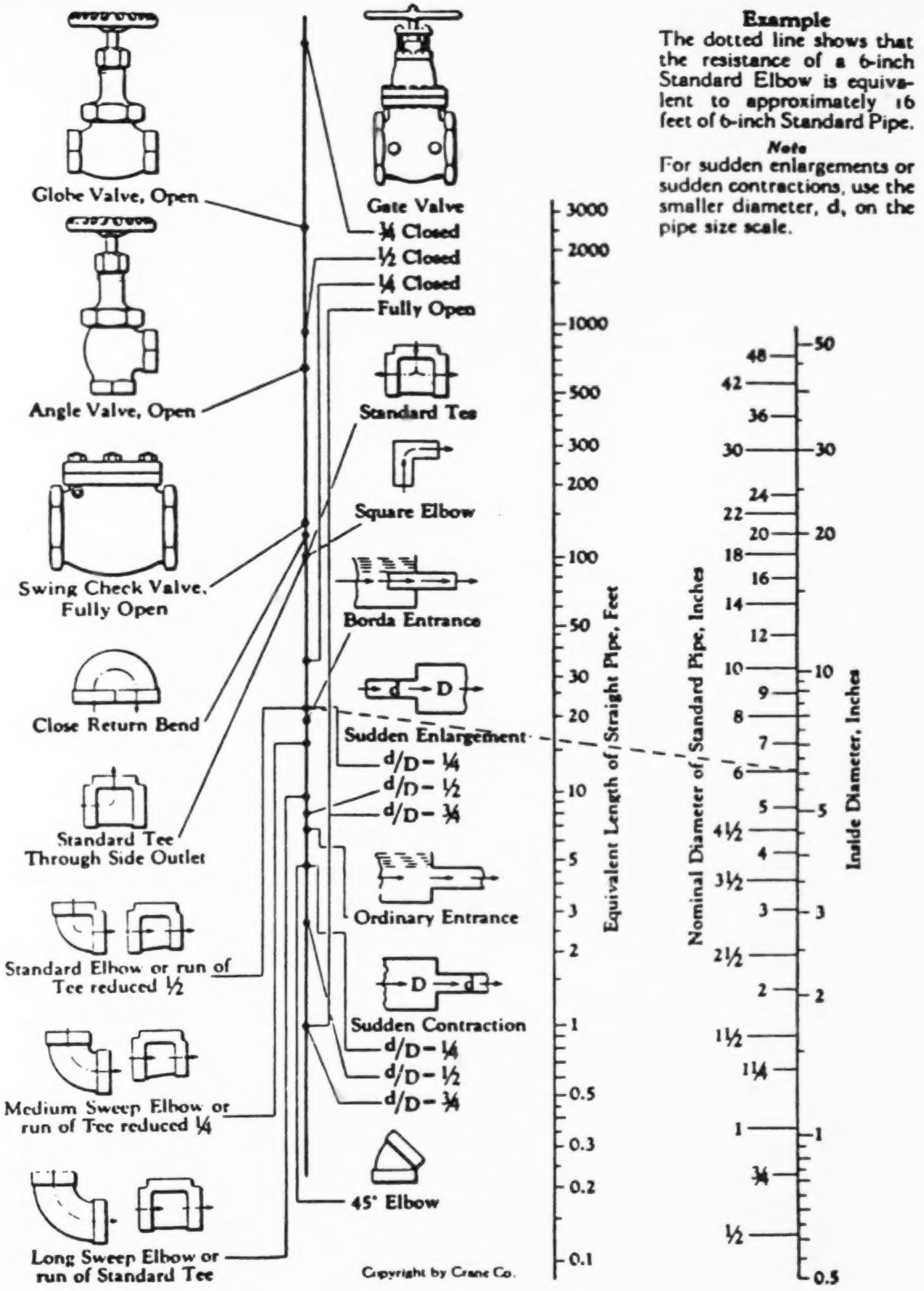
$$\begin{aligned}\text{Flow, gal/day} &= 1.4\ \text{MGD}\\ &= 1{,}400{,}000\ \text{gal/day}\end{aligned}$$

From Section A.30:

$$\begin{aligned}\text{Tank Volume, cu ft} &= (\text{Length, ft})(\text{Width, ft})(\text{Height, ft})\\ &= 60\ \text{ft} \times 30\ \text{ft} \times 8\ \text{ft}\\ &= 14{,}400\ \text{cu ft}\end{aligned}$$

Solution of Problem:

$$\begin{aligned}\text{Detention Time, hrs} &= \frac{(\text{Tank Volume, cu ft})(7.48\ \text{gal/cu ft})(24\ \text{hr/day})}{\text{Flow, gal/day}}\\ &= \frac{(14{,}400\ \text{cu ft})(7.48\ \text{gal/cu ft})(24\ \text{hr/day})}{1{,}400{,}000\ \text{gal/day}}\\ &= 1.85\ \text{hr}\end{aligned}$$



Example
The dotted line shows that the resistance of a 6-inch Standard Elbow is equivalent to approximately 16 feet of 6-inch Standard Pipe.

Note
For sudden enlargements or sudden contractions, use the smaller diameter, d, on the pipe size scale.

Copyright by Crane Co.

Fig. A.1 Resistance of valves and fittings to flow of water
(Reprinted by permission of Crane Co.)

U.S. GPM	0.5 in.		0.75 in.		1 in.		1.25 in.		1.5 in.		2 in.		2.5 in.	
	Vol.	Frict.	Vol.	Frict.	Vol.	Frict.	Vol.	Frict.	Vol.	Frict.	Vol.	Frict.	Vol.	Frict.
10	10.56	95.9	6.02	23.0	3.71	6.86	2.15	1.77	1.58	.83	.96	.25	.67	.11
20			12.0	86.1	7.42	25.1	4.29	6.34	3.15	2.94	1.91	.87	1.34	.36
30					11.1	54.6	6.44	13.6	4.73	6.26	2.87	1.82	2.01	.75
40					14.8	95.	8.58	23.5	6.30	10.79	3.82	3.10	2.68	1.28
50							10.7	36.0	7.88	16.4	4.78	4.67	3.35	1.94
60							12.9	51.0	9.46	23.2	5.74	6.59	4.02	2.72
70							15.0	68.8	11.03	31.3	6.69	8.86	4.69	3.63
80							17.2	89.2	12.6	40.5	7.65	11.4	5.36	4.66
90									14.2	51.0	8.60	14.2	6.03	5.82
100									15.8	62.2	9.56	17.4	6.70	7.11
120									18.9	88.3	11.5	24.7	8.04	10.0
140											13.4	33.2	9.38	13.5
160											15.3	43.0	10.7	17.4
180											17.2	54.1	12.1	21.9
200											19.1	66.3	13.4	26.7
220											21.0	80.0	14.7	32.2
240											22.9	95.0	16.1	38.1
260													17.4	44.5
280													18.8	51.3
300													20.1	58.5
350													23.5	79.2

U.S. GPM	3 in.		4 in.		5 in.		6 in.		8 in.		10 in.		12 in.		14 in.		16 in.		18 in.		20 in.	
	Vol.	Frict.	Vol.	Frict.	Vol.	Frict.	Vol.	Frict.	Vol.	Frict.	Vol.	Frict.	Vol.	Frict.	Vol.	Frict.	Vol.	Frict.	Vol.	Frict.	Vol.	Frict.
20	.91	.15																				
40	1.82	.55	1.02	.13																		
50	2.72	1.17	1.53	.28	.96	.08																
80	3.63	2.02	2.04	.48	1.28	.14	.91	.06														
100	4.54	3.10	2.55	.73	1.60	.20	1.13	.10														
120	5.45	4.40	3.06	1.03	1.92	.29	1.36	.13														
140	6.35	5.93	3.57	1.38	2.25	.38	1.59	.18														
160	7.26	7.71	4.08	1.78	2.57	.49	1.82	.23														
180	8.17	9.73	4.60	2.24	2.89	.61	2.04	.28														
200	9.08	11.9	5.11	2.74	3.21	.74	2.27	.35														
220	9.98	14.3	5.62	3.28	3.53	.88	2.50	.42	1.40	.10												
240	10.9	17.0	6.13	3.88	3.85	1.04	2.72	.49	1.53	.12												
260	11.8	19.8	6.64	4.54	4.17	1.20	2.95	.57	1.66	.14												
280	12.7	22.8	7.15	5.25	4.49	1.38	3.18	.66	1.79	.16												
300	13.6	26.1	7.66	6.03	4.81	1.58	3.40	.75	1.91	.18												
350			8.94	8.22	5.61	2.11	3.97	1.01	2.24	.24												
400			10.20	10.7	6.41	2.72	4.54	1.30	2.55	.30												
460			11.45	13.4	7.22	3.41	5.11	1.64	2.87	.38	1.84	.12										
500			12.8	16.6	8.02	4.16	5.67	2.02	3.19	.46	2.04	.15	1.42	.06								
550			14.0	19.9	8.82	4.98	6.24	2.42	3.51	.56	2.25	.18	1.56	.07								
600					9.62	5.88	6.81	2.84	3.83	.66	2.45	.21	1.70	.08	1.25	.04						
700					11.2	7.93	7.94	3.87	4.47	.88	2.86	.29	1.99	.12	1.46	.05						
800					12.8	10.22	9.08	5.06	5.11	1.14	3.27	.37	2.27	.15	1.67	.07						
900					14.4	12.9	10.2	6.34	5.74	1.44	3.68	.46	2.55	.18	1.88	.09						
1000							11.3	7.73	6.38	1.76	4.09	.57	2.84	.22	2.08	.11						
1100							12.5	9.80	7.02	2.14	4.49	.68	3.12	.27	2.29	.13						
1200							13.6	11.2	7.66	2.53	4.90	.81	3.40	.32	2.50	.15	1.91	.08				
1300							14.7	13.0	8.30	2.94	6.31	.95	3.69	.37	2.71	.17	2.07	.09				
1400									8.93	3.40	5.72	1.09	3.97	.43	2.92	.20	2.23	.10				
1500									9.57	3.91	6.13	1.25	4.26	.49	3.13	.23	2.34	.12				
1600									10.2	4.45	6.54	1.42	4.54	.55	3.33	.25	2.55	.13	2.02	.07		
1700									10.8	5.00	6.94	1.60	4.87	.62	3.54	.29	2.71	.15	2.15	.08		
1800									11.5	5.58	7.35	1.78	5.11	.70	3.75	.32	2.87	.16	2.27	.09		
1900									12.1	6.19	7.76	1.97	5.39	.77	3.96	.35	3.03	.18	2.40	.10		
2000									12.8	6.84	8.17	2.17	5.67	.86	4.17	.39	3.19	.20	2.52	.11		
2500											10.2	3.38	7.10	1.33	5.21	.60	3.99	.31	3.15	.17		
3000											12.3	4.79	8.51	1.88	6.25	.86	4.79	.44	3.78	.24	3.06	.14
3500											14.3	6.55	9.93	2.56	7.29	1.16	5.58	.58	4.41	.32	3.57	.19
4000													11.3	3.31	8.34	1.50	6.38	.75	5.04	.42	4.08	.24
4500													12.8	4.18	9.38	1.88	7.18	.95	5.67	.53	4.59	.31
5000													14.7	5.13	10.4	2.30	7.98	1.17	6.30	.65	5.11	.38
6000															12.5	3.31	9.57	1.66	7.56	.92	6.13	.53
7000															14.6	4.50	11.2	2.26	8.83	1.24	7.15	.72
8000																	12.8	2.96	10.09	1.61	8.17	.94
9000																	14.4	3.73	11.3	2.02	9.19	1.18
10000																			12.6	2.48	10.2	1.45

No allowance has been made for age, differences in diameter, or any other abnormal condition of interior surface. Any Factor of Safety must be estimated from the local conditions and the requirements of each particular installation. For general purposes, 15% is a responsible Factor of Safety.

Fig. A.2 Friction Loss for Water in Feet Per 100 Feet of Pipe

(Reprinted from the 10th Edition of the Standards of the Hydraulic Institute, 122 East 42nd Street, New York)

The remainder of this section discusses the details that must be considered in solving this problem.

A.92 Arrangement of Formula

Once the proper formula is selected, you may have to rearrange the terms to solve for the unknown term. From Section A.71, "Flow Rate," we can develop the formula:

$$\text{Velocity, ft/sec} = \frac{\text{Flow Rate, cu ft/sec}}{\text{Cross-Sectional Area, sq ft}}$$

or $$V = \frac{Q}{A}$$

In this equation if Q and A were given, the equation could be solved for V. If V and A were known, the equation would have to be rearranged to solve for Q. To move terms from one side of an equation to another, use the following rule:

When moving a term or number from one side of an equation to the other, move the numerator (top) of one side to denominator (bottom) of the other; or from the denominator (bottom) of one side to the numerator (top) of the other.

$$V = \frac{Q}{A} \text{ or } Q = AV \text{ or } A = \frac{Q}{V}$$

If the volume of a sedimentation tank and the desired detention time were given, the detention time formula could be rearranged to calculate the design flow.

$$\text{Detention Time, hrs} = \frac{(\text{Tank Vol., cu ft})(7.48\text{ gal/cu ft})(24\text{ hr/day})}{\text{Flow, gal/day}}$$

By rearranging the terms

$$\text{Flow, gal/day} = \frac{(\text{Tank Vol., cu ft})(7.48\text{ gal/cu ft})(24\text{ hr/day})}{\text{Detention Time, hrs}}$$

A.93 Unit Conversions

Each term in a formula or mathematical calculation must be of the correct units. The area of a rectangular clarifier (Area, sq ft = Length, ft × Width, ft) can't be calculated in square feet if the width is given as 246 inches or 20 feet 6 inches. The width must be converted to 20.5 feet. In the example problem, if the tank volume were given in gallons, then the 7.48 gal/cu ft would not be needed. THE UNITS IN A FORMULA MUST ALWAYS BE CHECKED BEFORE ANY CALCULATIONS ARE PERFORMED TO AVOID TIME-CONSUMING MISTAKES.

$$\text{Detention Time, hrs} = \frac{(\text{Tank Volume, cu ft})(7.48\text{ gal/cu ft})(24\text{ hr/day})}{\text{Flow, gal/day}}$$

$$= \cancel{\text{cu ft}} \times \frac{\cancel{\text{gal}}}{\cancel{\text{cu ft}}} \times \frac{\text{hr}}{\cancel{\text{day}}} \times \frac{\cancel{\text{day}}}{\cancel{\text{gal}}}$$

= hr (all other units cancel)

NOTE: We have hours = hr. One should note that the hour unit on both sides of the equation can be cancelled out and nothing would remain. This is one more check that we have the correct units. By rearranging the detention time formula, other unknowns could be determined.

If the design detention time and design flow were known, the required capacity of the tank could be calculated.

$$\text{Tank Volume, cu ft} = \frac{(\text{Detention Time, hr})(\text{Flow, gal/day})}{(7.48\text{ gal/cu ft})(24\text{ hr/day})}$$

If the tank volume and design detention time were known, the design flow could be calculated.

$$\text{Flow, gal/day} = \frac{(\text{Tank Volume, cu ft})(7.48\text{ gal/cu ft})(24\text{ hr/day})}{\text{Detention Time, hrs}}$$

Rearrangement of the detention time formula to find other unknowns illustrates the need to always use the correct units.

A.94 Calculations

Sections A.12, "Multiplication," and A.13, "Division," outline the steps to follow in mathematical calculations. In general, do the calculations inside parentheses ( ) first and brackets [ ] next. Calculations should be done above and below the division line before dividing.

$$\text{Detention Time, hrs} = \frac{[(\text{Tank, Volume, cu ft})(7.48\text{ gal/cu ft})(24\text{ hr/day})]}{\text{Flow, gal/day}}$$

$$= \frac{[(14{,}400\text{ cu ft})(7.48\text{ gal/cu ft})(24\text{ hr/day})]}{1{,}400{,}000\text{ gal/day}}$$

$$= \frac{2{,}585{,}088\text{ gal-hr/day}}{1{,}400{,}000\text{ gal/day}}$$

$$= 1.85\text{, or}$$

$$\doteq 1.9\text{ hr}$$

A.95 Significant Figures

In calculating the detention time in the previous section, the answer is given as 1.9 hr. The answer could have been calculated:

$$\text{Detention Time,hrs} = \frac{2{,}585{,}088\text{ gal-hr/day}}{1{,}400{,}000\text{ gal/day}}$$

$$= 1.846491429 \ldots \text{ hours}$$

How does one know when to stop dividing? Common sense and significant figures both help.

First, consider the meaning of detention time and the measurements that were taken to determine the knowns in the formula. Detention time in a tank is a theoretical value and assumes that all particles of water throughout the tank move through the tank at the same velocity. This assumption is not correct; therefore, detention time can only be a representative time for some of the water particles.

Will the flow of 1.4 MGD be constant throughout the 1.9 hours, and is the flow exactly 1.4 MGD, or could it be 1.35 MGD or 1.428 MGD? A carefully calibrated flow meter may give a reading within 2% of the actual flow rate. Flows into a tank fluctuate and flow meters do not measure flows extremely accurately; so the detention time again appears to be a representative or typical detention time.

Tank dimensions are probably satisfactory within 0.1 ft. A flow meter reading of 1.4 MGD is less precise and it could be 1.3 or 1.5 MGD. A 0.1 MGD flow meter error when the flow is 1.4 MGD is (0.1/1.4) × 100% = 7% error. A detention time of 1.9 hours, based on a flow meter reading error of plus or minus 7%, also could have the same error or more, even if the flow was constant. Therefore, the detention time error could be 1.9 hours × 0.07 = ± 0.13 hours.

In most of the calculations in the operation of water treatment plants, the operator uses measurements determined in the lab or read from charts, scales, or meters. The accuracy of every measurement depends on the sample being measured, the equipment doing the measuring, and the operator reading or measuring the results. Your estimate is no better than the least precise measurement. Do not retain more than one doubtful number.

To determine how many figures or numbers mean anything in an answer, the approach called "significant figures" is used. In the example the flow was given in two significant figures (1.4 MGD), and the tank dimensions could be considered accurate to the nearest tenth of a foot (depth = 9.0 ft) or two significant figures. Since all measurements and the constants contained two significant figures, the results should be reported as two significant figures or 1.9 hours. The calculations are normally carried out to three significant figures (1.85 hours) and rounded off to two significant figures (1.9 hours).

Decimal points require special attention when determining the number of significant figures in a measurement.

Measurement	Significant Figures
0.00325	3
11.078	5
21,000.	2

Example: The distance between two points was divided into three sections, and each section was measured by a different group. What is the distance between the two points if each group reported the distance if measured as follows:

Group	Distance, ft	Significant Figures
A	11,300.	3
B	2,438.9	5
C	87.62	4
Total Distance	13,826.52	

Group A reported the length of the section it measured to three significant figures; therefore, the distance between the two points should be reported as 13,800 feet (3 significant figures).

When adding, substracting, multiplying, or dividing, the number of significant figures in the answer should not be more than the term in the calculations with the least number of significant figures.

A.96 Check Your Results

After having completed your calculations, you should carefully examine your calculations and answer. Does the answer seem reasonable? If possible, have another operator check your calculations before making any operational changes.

A.10 BASIC CONVERSION FACTORS (ENGLISH SYSTEM)

UNITS		
1,000,000	= 1 Million	1,000,000/1 Million
LENGTH		
12 in	= 1 ft	12 in/ft
3 ft	= 1 yd	3 ft/yd
5280 ft	= 1 mi	5280 ft/mi
AREA		
144 sq in	= 1 sq ft	144 sq in/sq ft
43,560 sq ft	= 1 acre	43,560 sq ft/ac
VOLUME		
7.48 gal	= 1 cu ft	7.48 gal/cu ft
1000 m*L*	= 1 liter	1000 m*L*/*L*
3.785 *L*	= 1 gal	3.785 *L*/gal
231 cu in	= 1 gal	231 cu in/gal
WEIGHT		
1000 mg	= 1 gm	1000 mg/gm
1000 gm	= 1 kg	1000 gm/kg
454 gm	= 1 lb	454 gm/lb
2.2 lbs	= 1 kg	2.2 lbs/kg
POWER		
0.746 kw	= 1 HP	0.746 kw/HP
DENSITY		
8.34 lbs	= 1 gal	8.34 lbs/gal
62.4 lbs	= 1 cu ft	62.4 lbs/cu ft
DOSAGE		
17.1 mg/*L*	= 1 grain/gal	17.1 mg/*L*/gpg
64.7 grains	= 1 mg	64.7 grains/mg
PRESSURE		
2.31 ft water	= 1 psi	2.31 ft water/psi
0.433 psi	= 1 ft water	0.433 psi/ft water
1.133 ft water	= 1 in Mercury	1.133 ft water/in Mercury
FLOW		
694 GPM	= 1 MGD	694 GPM/MGD
1.55 CFS	= 1 MGD	1.55 CFS/MGD
TIME		
60 sec	= 1 min	60 sec/min
60 min	= 1 hr	60 min/hr
24 hr	= 1 day	24 hr/day

A.11 SUMMARY OF FORMULAS (ENGLISH SYSTEM)

A.110 Length

LENGTH OR CIRCUMFERENCE OF A CIRCLE:

Length, ft = 3.14 (Diameter, ft)

A.111 Area

RECTANGLE:

Area, sq ft = (Length, ft)(Width, ft)

TRIANGLE:

Area, sq ft = (1/2)(Base, ft)(Height, ft)

CIRCLE:

Area, sq ft = 0.785 $(\text{Diameter, ft})^2$

CYLINDER (wall):

Area, sq ft = 3.14 (Diameter, ft)(Height, ft)

SPHERE:

Area, sq ft = 3.14 $(\text{Diameter, ft})^2$

A.112 Volume

RECTANGLE:

Volume, cu ft = (Length, ft)(Width, ft)(Height, ft)

CYLINDER:

Volume, cu ft = 0.785 (Diameter, ft)^2 (Height, ft)

SPHERE:

Volume, cu ft = 0.524 (Diameter, ft)^3

A.113 Velocity and Flow

$$\text{Velocity, ft sec} = \frac{\text{Distance Traveled, ft}}{\text{Time, sec}}$$

or

$$\text{Velocity, ft/sec} = \frac{\text{Flow Rate, cu ft/sec}}{\text{Cross-Sectional Area, sq ft}}$$

$$\text{Ave. flow, MGD} = \frac{\text{Sum of daily flows, MGD}}{\text{Number of daily flows}}$$

A.114 Slope or Grade

$$\text{Grade, ft/ft} = \frac{\text{Rise, ft}}{\text{Run, ft}}$$

A.115 Chemical Doses

Chlorine Demand, mg/*L* = Chlorine Dose, mg/*L* - Chlorine Residual, mg/*L*

Chlorine Feed Rate, lbs/day = (Dose, mg/*L*)(Flow, MGD)(8.34 lbs/gal)

Chemicals, lbs = (Concentration, mg/*L*)(Volume, MG)(8.34 lbs/gal)

A.116 Excavation and Paving

$$\text{Trench Width at Top, ft} = \text{Base, ft} + \frac{(2)(\text{Depth, ft})}{\text{Side Slope}}$$

$$\text{Where Slide Slope} = \frac{\text{Rise, ft}}{\text{Run, ft}}$$

A.117 Electricity

Ohm's Law E = IR

or

EMF, Volts = (Current, amps, (Resistance, ohms)

Power, watts = (E, volts)(I, amps)

Power, watts = (I, amps)^2(R, ohms)

Motor Output, watts = (Power, watts)(Power factor)(Motor efficiency)

A.118 Pumps

$$\text{Water, HP} = \frac{(\text{Flow, gpm})(\text{H, ft})}{3960}$$

$$\text{Brake, HP} = \frac{(\text{Flow, gpm})(\text{H, ft})}{(3960)(E_p)}$$

$$\text{Motor, HP} = \frac{(\text{Flow, gpm})(\text{H, ft})}{(3960)(E_p)(E_m)}$$

$$\text{Efficiency, \%} = \frac{\text{Output}}{\text{Input}} \times 100\%$$

A.119 Storage Tanks, Wet Wells and Storm Water Storage Basins

$$\text{Fill time, hrs} = \frac{(\text{Tank Volume, cu ft})(7.5\text{ gal/cu ft})(24\text{ hr/day})}{\text{Flow, gal/day}}$$

A.12 SOLUTIONS TO PROBLEMS

In this section typical math problems that have to be solved by wastewater collection system operators are presented. If a particular problem is too difficult, go to the next problem and try it. For example, if the problems on excavation become too difficult, try the problems on electricity.

A. Population Equivalent

1. A 24-inch sewer carries an average daily flow of 5 MGD. If the average daily flow per person from the area served is 100 gpcd* (gallons per capita or person per day), how many people discharge into the wastewater collection system?

Known	Unknown
Diameter, in = 24 in	Pop. served, persons
Flow, MGD = 5 MGD	
or = 5,000,000 gal/day	
Pop. Equiv., gpcd = 100 gpcd	

How many people discharge into collection system?

$$\begin{aligned}\text{Pop. served, persons} &= \frac{\text{Flow, gal/day}}{\text{Pop. Equiv., gal/person/day}}\\ &= \frac{5{,}000{,}000\text{ gal/day}}{100\text{ gal/person/day}}\\ &= \underline{\underline{50{,}000\text{ persons}}}\end{aligned}$$

ANALYSIS OF RESULTS

Calculated Pop.	Actual Pop.	Comments
50,000	50,820	Results appear OK
50,000	38,130	Since calculated population is considerably greater than actual, either there is considerable industrial discharge or inflow/infiltration. *FIND THE CAUSE OF ADDITIONAL FLOW.*
50,000	63,617	Since calculated population is considerably less than actual population, apparently there is considerable exfiltration. *FIND THE CAUSE OR LOCATION OF EXFILTRATION.*

2. An industry discharges an average of 5,230 gallons per day. What is the population equivalent from this industry? Assume a population equivalent flow of 100 gpcd.

Known	Unknown
Average flow, gal/day = 5,320 gal/day	Pop. Equiv., persons
Pop. Equiv., gpcd = 100 gpcd	

What is the population equivalent from this industry?

$$\begin{aligned}\text{Pop. Equiv., persons} &= \frac{\text{Flow, gal/day}}{\text{Pop. Equiv., gal/person/day}}\\ &= \frac{5{,}320\text{ gal/day}}{100\text{ gal/person/day}}\\ &= 53.2\\ \text{or } &= \underline{\underline{53\text{ persons}}}\end{aligned}$$

B. Velocity and Flow

3. Estimate the velocity of wastewater flowing in a 12-inch sewer. A red dye is poured into an upstream manhole. Three minutes later the dye first appears in a manhole 400 feet downstream. The dye disappears 3 minutes and 40 seconds after the dye is poured into the upstream manhole.

Known	Unknown
Diameter, in = 12 in	Velocity, ft/sec
Time, sec t_1 = 3 min	
Time, sec t_2 = 3 min 40 sec	
Distance, ft = 400 feet	

---

*Usually about 70% of the water supply rate.

Convert travel time to seconds.

$$\begin{aligned}\text{Time, sec. } t_1 &= 3 \text{ min}\\ &= (3\text{ min})(60\text{ sec/min})\\ &= 180\text{ sec}\end{aligned}$$

$$\begin{aligned}\text{Time, sec } t_2 &= 3\text{ min } 40\text{ sec}\\ &= (3\text{ min})(60\text{ sec/min}) + 40\text{ sec}\\ &= 180\text{ sec} + 40\text{ sec}\\ &= 220\text{ sec}\end{aligned}$$

$$\begin{aligned}\text{Ave. Time, Sec} &= 1/2\,(t_1 + t_2)\\ &= 1/2\,(180\text{ sec} + 220\text{ sec})\\ &\ 200\text{ sec}\end{aligned}$$

Estimate velocity in feet per second

$$\begin{aligned}\text{Velocity, ft/sec} &= \frac{\text{Distance, ft}}{\text{Ave. Time, sec}}\\ &= \frac{400\text{ ft}}{200\text{ sec}}\\ &= \underline{\underline{2.0\text{ ft/sec}}}\end{aligned}$$

ANALYSIS OF RESULTS

Velocity is a minimum recommended velocity of 2 fps. Problems of solids deposition could result at low flows.

4. A float (marked stick) is dropped into a manhole to estimate the velocity of the wastewater. Two minutes and 30 seconds later the float arrives in a manhole 450 feet downstream.

Known		Unknown
Time, sec	= 2 min 30 sec	Velocity, ft/sec
Distance, ft.	= 450 ft	

Convert travel time to seconds.

$$\begin{aligned}\text{Time, sec} &= 2\text{ min } 30\text{ sec}\\ &= (2\text{ min})(60\text{ sec/min}) + 30\text{ sec}\\ &= 120\text{ sec} + 30\text{ sec}\\ &= 150\text{ sec}\end{aligned}$$

Estimate velocity in feet per second.

$$\begin{aligned}\text{Velocity ft/sec} &= \frac{\text{Distance, ft}}{\text{Time, sec}}\\ &= \frac{450\text{ ft}}{150\text{ sec}}\\ &= \underline{\underline{3.0\text{ ft/sec}}}\end{aligned}$$

NOTE — Velocity of floats is often 10 to 15 percent higher than the average velocity.

Convert float velocity to average velocity. Assume float velocity 10 percent too high.

$$\begin{aligned}\text{Ave. Vel., ft/sec} &= \text{Float vel., ft/sec} - (\text{Float vel., ft/sec})(\text{fraction too high})\\ &= 3.0\text{ ft/sec} - (3.0\text{ ft/sec})\left(\frac{10\%}{100\%}\right)\\ &= 3.0\text{ ft/sec} - 3.0\text{ ft/sec}\,(0.1)\\ &= 3.0\text{ ft/sec} - 0.3\text{ ft/sec}\\ &= \underline{\underline{2.7\text{ ft/sec}}}\end{aligned}$$

5. Determine the flow in a 12-inch sewer flowing full if the average velocity is 2 fps.

Known		Unknown
Diameter, in	= 12 in	Flow, cfs
Velocity, ft/sec	= 2 ft/sec	

Calculate area of 12-inch sewer.

$$\begin{aligned}\text{Area, sq in} &= \frac{\pi}{4} D^2\\ &= \frac{3.14}{4}(12\text{ in})^2\\ &= (0.785)(144\text{ sq in})\\ &= 113\text{ sq in}\end{aligned}$$

or

$$\begin{aligned}\text{Area, sq ft} &= \frac{(\text{Area, sq in})}{(144\text{ sq in/sq ft})}\\ &= \frac{113\text{ sq in}}{144\text{ sq in/sq ft}}\\ &= 0.785\text{ sq ft}\end{aligned}$$

Determine the flow in cubic feet per second.

$$Q = AV$$

or

$$\begin{aligned}\text{Flow, cfs} &= (\text{Area, sq ft})(\text{Velocity, ft/sec})\\ &= (0.785\text{ sq ft})(2\text{ ft/sec})\\ &= \underline{\underline{1.57\text{ cu ft/sec}}}\end{aligned}$$

6. Convert a flow of 2 cfs to million gallons per day (MGD) and gallons per minute (GPM).

Known	Unknown
Flow, cfs = 2 cfs	Flow, MGD
	Flow, GPM

CONVERSION FACTORS

1 cfs = 0.646 MGD = 449 GPM

or

1.547 cfs = 1 MGD = 694 GPM

Convert 2 cfs to flow in MGD.

$$\begin{aligned}\text{Flow, MGD} &= (\text{Flow, cfs})\,\frac{(0.646\text{ MGD})}{1\text{ cfs}}\\ &= (2\text{ cfs})\,\frac{(0.646\text{ MGD})}{1\text{ cfs}}\\ &= \underline{\underline{1.292\text{ MGD}}}\end{aligned}$$

$$\begin{aligned}\text{Flow, GPM} &= (\text{Flow, cfs})\,\frac{(449\text{ GPM})}{1\text{ cfs}}\\ &= (2\text{ cfs})\,\frac{(449\text{ GPM})}{1\text{ cfs}}\\ &= \underline{\underline{898\text{ GPM}}}\end{aligned}$$

7. The depth of flow in a 15-inch diameter sewer is 6 inches. Determine the cross-sectional area of the flow.

Known	Unknown
D or Diameter, in = 15 in	Cross-sectional area, sq ft
d or Depth, in = 6 in	

To determine the cross-sectional area for a sewer pipe flowing partially full use the following steps:

Find the value for the depth, d, divided by the diameter, D.

$$\begin{aligned}\frac{d,\text{ in}}{D,\text{ in}} &= \frac{6\text{ in}}{15\text{ in}}\\ &= 0.40\end{aligned}$$

From Table 3.4 for d/D = 0.40, Factor = 0.2934.

$$\text{Pipe cross-sectional area, sq ft} = \frac{(\text{Factor})(\text{Diameter, in})^2}{144 \text{ sq in/sq ft}}$$

$$= \frac{(0.2934)(15 \text{ in})^2}{144 \text{ sq in/sq ft}}$$

$$= \underline{\underline{0.46 \text{ sq ft}}}$$

8. The slope of an 18-inch diameter sewer is 0.003 ft per ft, the pipe is flowing one-half full and the coefficient of pipe roughness is assumed to be 0.013. Determine the velocity and quantity (flow rate) of wastewater conveyed by the sewer.

Known	Unknown
Slope, S, ft/ft = 0.003 ft/ft	Velocity, V, ft/sec
Diameter, D, in = 15 in	
Roughness, n = 0.013	

1. Calculate the cross-sectional area of the pipe when it is flowing half full.

$$\frac{\text{depth}}{\text{Diameter}} = \frac{(1/2)(15 \text{ in})}{15 \text{ in}}$$

$$= \frac{7.5 \text{ in}}{15 \text{ in}}$$

$$= 0.50$$

From Table 3.4. if d/D = 0.50, Factor = 0.3927.

2. Calculate the pipe cross-sectional flow area.

$$\text{Pipe flow area sq ft} = \frac{(\text{Factor})(\text{Diameter, in})^2}{144 \text{ sq in/sq ft}}$$

$$= \frac{(0.3927)(18 \text{ in})^2}{144 \text{ sq in/sq ft}}$$

$$= 0.88 \text{ sq ft}$$

3. Calculate the wetted perimeter for a pipe flowing half full.

$$\text{Wetted perimeter, P, ft} = \frac{(1/2)(3.14)(\text{Diameter, in})}{12 \text{ in/ft}}$$

$$= \frac{(0.5)(3.14)(18 \text{ in})}{12 \text{ in/ft}}$$

$$= 2.36 \text{ ft}$$

4. Calculate the hydraulic radius, R, in feet.

$$\text{Hydraulic radius, Rt, ft} = \frac{\text{Flow area, A, sq ft}}{\text{Wetted perimeter, P, ft}}$$

$$= \frac{0.88 \text{ sq ft}}{2.36 \text{ ft}}$$

$$= 0.37 \text{ ft}$$

5. Calculate the flow velocity in feet per second.

$$\text{Velocity, V, ft/sec} = \frac{1.486}{0.013}(0.37 \text{ ft})^{2/3}(0.003)^{1/2}$$

$$= (114.3)(0.515)(0.055)$$

$$= 3.2 \text{ ft/sec}$$

6. Calculate the quantity of flow in cubic feet per second.

$$\text{Quantity, Q, CFS} = (\text{Area, sq ft})(\text{Velocity, ft/sec})$$

$$= (0.88 \text{ sq ft})(3.2 \text{ ft/sec})$$

$$= 2.8 \text{ cu ft/sec}$$

7. Convert the quantity of flow from cubic feet per second to million gallons per day, MGD.

$$\text{Quantity, Q, MGD} = \frac{(\text{Quantity, Q, cu ft/sec})(7.48 \text{ gal/cu ft})(60 \text{ sec/min})(60 \text{ min/hr})(24 \text{ hr/day})}{1{,}000{,}000/\text{M}}$$

$$= \frac{\text{Quantity, Q, cu ft/sec}}{1.55 \text{ cu ft/sec/MGD}}$$

$$= \frac{2.8 \text{ cu ft/sec}}{1.55 \text{ cu ft/sec/MGD}}$$

$$= \underline{\underline{1.8 \text{ MGD}}}$$

9. What was the average daily flow for a lift station given the following flow totalizer readings?

8:00 a.m., Monday, August 11	113,428,731 gallons
8:00 a.m., Monday, August 18	121,987,566 gallons

Known	Unknown
Totalizer Readings, gallons	Ave. Flow, MGD
Time, days = 7 days	

Determine total flow for 7 days in gallons.

	Final Reading, gal	= 121,987,566 gal
	Initial Reading, gal	= 113,428,731 gal
	Total flow, gal	= 8,558,835 gal
or	Total flow, MG	= 8.559 MG

Calculate average flow, MGD

$$\text{Ave. flow, MGD} = \frac{\text{Total flow, MG}}{\text{Time, days}}$$

$$= \frac{8.559 \text{ MG}}{7 \text{ days}}$$

$$= \underline{\underline{1.22 \text{ MGD}}}$$

10. Estimate the average daily flow for a lift station given the following daily flow readings.

Day	Mon	Tues	Wed	Thurs	Fri	Sat	Sun
Flow, MG or MGD*	1.68	1.53	1.21	1.16	1.05	1.47	0.90

Known	Unknown
Daily flows, MGD	Ave. daily flow, MGD

Estimate average daily flow, MGD.

$$\text{Ave. daily flow, MGD} = \frac{\text{Sum of daily flows, MGD}}{\text{Number of daily flows}}$$

$$= \frac{1.68 + 1.53 + 1.21 + 1.16 + 1.05 + 1.47 + 0.90}{7}$$

$$= \frac{9.00 \text{ MGD}}{7}$$

$$= 1.286 \text{ MGD}$$

$$= \underline{\underline{1.29 \text{ MGD}}}$$

*NOTE: 1.68 MG flowed during one day so we had a flow of 1.68 MGD.

C. Pipes

11. A piece of pipe is 23 feet long and is to be cut into 4 equal pieces. Each piece will be ____ ft ____ inches long.

Known	Unknown
Length, ft. = 23 ft	Length, ft and inches
Want 4 equal pieces	

Determine length in feet and then feet and inches.

$$\text{Length, ft} = \frac{\text{Total length, ft}}{\text{Number of equal pieces}}$$

$$= \frac{23 \text{ feet}}{4 \text{ pieces}}$$

$$= 5.75 \text{ ft}$$

or

$$\text{Length, ft \& in} = 5 \text{ ft} + (0.75 \text{ ft})(12 \text{ in/ft})$$

$$= \underline{\underline{5 \text{ ft } 9 \text{ in}}}$$

12. A sewer has failed and 127 feet of 8-inch pipe must be replaced. How many 5-foot sections of pipe will be required?

Known	Unknown
Length, ft = 127 ft	Number of sections
Section, ft = 5 ft	

Calculate number of sections needed.

$$\text{No. of sections} = \frac{\text{Total length, ft}}{\text{Length, ft/section}}$$

$$= \frac{127 \text{ ft}}{5 \text{ ft/section}}$$

$$= 25.4 \text{ sections}$$

$$= \underline{\underline{26 \text{ sections needed}}}$$

13. A sewer with a 12-inch diameter has how many times more carrying capacity than a 4-inch diameter sewer? Assume the velocity is the same in each sewer.

Known	Unknown
Diameter, in = 12 in Diameter, in = 4 in Velocity same in each sewer	How many times more carrying capacity?

Determine how many times more carrying capacity.

$$Q = A\,V \text{ and } A = 0.785\,D^2$$

$$\frac{12 \text{ in diameter}}{4 \text{ in diameter}} = \frac{12 \text{ inch pipe } Q}{4 \text{ inch pipe } Q}$$

$$= \frac{A\,V}{A\,V}$$

$$= \frac{\cancel{0.785}\,(12 \text{ in})^2\,\cancel{V}}{\cancel{0.785}\,(4 \text{ in})^2\,\cancel{V}}$$

$$= \frac{(12 \text{ in})^2}{(4 \text{ in})^2}$$

$$= \frac{144}{16}$$

$$= \underline{\underline{9 \text{ times}}}$$

or

12-inch sewer has 9 times capacity of 4-inch sewer.

D. Slope or Grade

14. If the total fall in a ditch is 14 feet in 1000 feet, what is the grade in ft/ft and in percent?

Known	Unknown
Fall, ft = 14 ft	Grade, ft/ft
Length, ft = 1000 ft	Grade, %

Calculate grade.

$$\text{Grade, ft/ft} = \frac{\text{Rise, ft}}{\text{Run, ft}}$$

$$= \frac{14 \text{ ft}}{1000 \text{ ft}}$$

$$= \underline{\underline{0.014 \text{ ft/ft}}}$$

or

$$\text{Grade, \%} = (0.014 \text{ ft/ft})(100\%)$$

$$= \underline{\underline{1.4\%}}$$

15. How many feet drop in 400 feet of 8-inch sewer with a 0.045 ft/ft slope?

Known	Unknown
Diameter, in = 8 in	Drop, ft
Length, ft = 400 ft	
Slope = 0.045 ft/ft	

Calculate drop in feet.

$$\text{Slope, ft/ft} = \frac{\text{Rise, ft}}{\text{Run, ft}}$$

Rearrange equation.

$$\text{Rise, ft} = (\text{Slope, ft/ft})(\text{Run, ft})$$

$$= (0.045 \text{ ft/ft})(400 \text{ ft})$$

$$= \underline{\underline{18.0 \text{ ft}}}$$

16. What is the slope on an 8-inch sewer that is 400 feet long if the invert elevation of the upstream manhole is 428.31 feet and the invert elevation of the downstream manhole is 423.89 feet?

Known	Unknown
Diameter, in = 8 in	Slope, ft/ft
Length, ft = 400 ft	
Upstream MH = 428.31 ft	
Downstream MH = 423.89 ft	

Find difference in elevation or drop between manholes.

Upstream MH = 428.31 ft
Downstream MH = 423.89 ft
Drop, ft = 4.42 ft

Calculate slope.

$$\text{Slope, ft/ft} = \frac{\text{Rise, ft}}{\text{Run, ft}}$$

$$= \frac{4.42 \text{ ft}}{400 \text{ ft}}$$

$$= 0.01105$$

$$= \underline{\underline{0.011 \text{ ft/ft}}}$$

17. A 10-inch sewer has been televised and the footage meter between two manholes indicates the distance is 437 feet. An actual field measurement verifies the distance shown on the plans of 400 feet.

    a. What is the percent error in the length?

    b. If the TV camera was pulled from the upstream to the downstream manhole, what is the difference from each manhole to a broken pipe at distance 328 feet?

Known	Unknown
Diameter, in = 10 ft	a. Percent error
Meter distance, ft = 437 ft	b. Location of broken pipe
Actual distance, ft = 400 ft	
Broken pipe, ft = 328 ft	

a. Calculate percent error.

$$\text{Error, \%} = \frac{(\text{Meter, dist., ft} - \text{Actual dist., ft})\ 100\%}{\text{Actual dist., ft}}$$

$$= \frac{(437\text{ ft} - 400\text{ ft})\ 100\%}{400\text{ ft}}$$

$$= \frac{(37\text{ ft})(100\%)}{400\text{ ft}}$$

$$= \underline{\underline{9.25\%\text{ error}}}$$

NOTE: Error is greater than 1 percent so all distances in log book must be corrected. Footage meter should be recalibrated.

b. Determine location of broken pipe.

$$\text{Location, ft from Upper MH} = \frac{(\text{Meter from upper MH, ft})(\text{Actual total, ft})}{(\text{Meter Total, ft})}$$

$$= \frac{(328\text{ ft})(400\text{ ft})}{(437\text{ ft})}$$

$$= \frac{131{,}200\text{ ft}}{437}$$

$$= \underline{\underline{300\text{ ft}}}$$

$$\text{Location, ft from Lower MH} = \frac{(\text{Meter from lower MH, ft})(\text{Actual total, ft})}{(\text{Meter Total, ft})}$$

$$= \frac{(437\text{ ft} - 328\text{ ft})(400\text{ ft})}{(437\text{ ft})}$$

$$= \frac{(109\text{ ft})(400\text{ ft})}{437\text{ ft}}$$

$$= \frac{43{,}600\text{ ft}}{437\text{ ft}}$$

$$= \underline{\underline{100\text{ ft}}}$$

NOTE: Distance from upper and lower manholes to broken pipe (300 ft + 100 ft = 400 ft) is equal to the actual distance so the calculations check.

E. Leak Test

18. An 8-inch sewer 400 feet long is given a water leak test. The downstream manhole is plugged where the line enters the manhole. There are no service lines connected to the test line. At 9:00 a.m. in the morning the 36-inch upstream manhole was filled to the bottom of the cone. By 5:00 p.m. the water had dropped 4.0 feet. Calculate the leakage in terms of gallons per day per inch of sewer diameter per mile of sewer.

Known	Unknown
Diameter, in = 8 in	Leakage in gpd/in/mi
Length, ft = 400 ft	
Time, hr = 8 hr	
Diameter, ft = 3 ft	
Height, ft = 4 ft	

Calculate the volume of water that leaked.

$$\text{Volume, cu ft} = (\text{Area, sq ft})(\text{Height, ft})$$

$$= (0.785)(3\text{ ft})^2(4.0\text{ ft})$$

$$= 28.27\text{ cu ft}$$

$$\text{Volume, gal} = (28.27\text{ cu ft})(7.48\text{ gal/cu ft})$$

$$= 211.5\text{ gal}$$

Calculate leakage in gallons per day.

$$\text{Leakage, gpd} = \frac{\text{Volume, gal}}{\text{Time, day}}$$

$$= \frac{(211.5\text{ gal})(24\text{ hr/day})}{(8\text{ hr})}$$

$$= 634.5\text{ gpd}$$

Calculate leakage in gpd/inch of sewer.

$$\text{Leakage, gpd/in} = \frac{\text{Leakage, gpd}}{\text{Sewer diameter, in}}$$

$$= \frac{634.5\text{ gpd}}{8\text{ in}}$$

$$= 79.3\text{ gpd/in}$$

Calculate leakage in gpd/in/mile of sewer.

$$\text{Leakage, gpd/in/mi} = \frac{(79.3\text{ gpd/in})(5280\text{ ft/mi})}{(\text{Length, ft})}$$

$$= \frac{(79.3\text{ gpd/in})(5280\text{ ft/mi})}{400\text{ ft}}$$

$$= \underline{\underline{1047\text{ gpd/in/mi}}}$$

NOTE: Maximum allowable leakage is usually 250 to 500 gpd/inch of sewer diameter/mile of sewer. Therefore sewer fails leak test. There should be very little leakage from a properly constructed sewer. Try to find all leaks and correct them.

19. Determine the force against each plug is a pipe is 18-inches in diameter and the test pressure is 5 psi.

Known	Unknown
Pipe Diameter, in = 18 in	Force, lbs
Test Pressure, psi = 5 psi	

1. Calculate the surface area of the plug.

$$\text{Surface Area, sq in} = (0.785)(\text{Diameter, in})^2$$

$$= (0.785)(18\text{ in})^2$$

$$= 254\text{ sq in}$$

2. Determine force against plug.

Force, lbs = (Test Pressure, psi)(Surface Area, sq in)
= (5 lbs/sq in)(254 sq in)
= 1,270 pounds

How would you like to be clobbered by a force of 1,270 pounds?

CAUTION: *NEVER ALLOW ANY PERSON TO ENTER A MANHOLE WHILE AIR IS BEING FORCED INTO A PIPE WITH PLUGS IN PLACE OR WHEN ANY PRESSURE REMAINS BEHINDS PLUGS.*

F. Map and Blueprint Reading

20. The distance between two manholes on a map is measured as 15/16 of an inch. Scale for the map is 1 inch equals 800 feet. Estimate the actual distance between the two manholes.

Known	Unknown
Distance, in = 15/16 in	Actual distance, ft
Scale, 1 in = 800 ft	

Estimate actual distance in feet.

$$\frac{\text{Actual distance, ft}}{\text{Measure distance, in}} = \frac{800\text{ ft}}{1\text{ inch}}$$

$$\begin{aligned}\text{Actual distance, ft} &= \frac{(800\text{ ft})(15/16\text{ in})}{(1\text{ in})}\\ &= \frac{(800\text{ ft})(15)}{16}\\ &= \frac{12000}{16}\\ &= \underline{\underline{750\text{ ft}}}\end{aligned}$$

G. Chemical Doses

CHLORINATION

21. Chlorine Demand

Determine the chlorine demand* of an effluent from a wastewater treatment plant if the chlorine dose is 10.0 mg/*L* and the chlorine residual is 1.1 mg/*L*.

Known	Unknown
Chlorine Dose = 10.0 mg/*L*	Chlorine Demand, mg/*L*
Chlorine Residual = 1.1 mg/*L*	

Chlorine Demand, mg/*L* = Chlor. Dose, mg/*L* - Chlor. Resid., mg/*L*
= 10.0 mg/*L* - 1.1 mg/*L*
= 8.9 mg/*L*

22. Chlorine Feed Rate

To control hydrogen sulfide and odors in an 8-inch sewer, the chlorine dose must be 10 mg/*L* when the flow is 0.37 MGD. Determine the chlorinator setting (feed rate) in pounds per day.

Known	Unknown
Dose = 10 mg/*L*	Chlorinator Setting, lbs/day
Flow = 0.37 MGD	

Chlorine Feed Rate, lbs/day = (Dose, mg/*L*)(Flow, MGD)(8.34 lb/gal)
= (10 mg/*L*)(0.37 MGD)(8.34 lb/gal)
= 30.9
or = 31 lbs/day

ROOT CONTROL

23. Quantity of Chemicals

A company contends their product is effective in controlling roots at a concentration of 100 mg/*L* if the contact time is 30 minutes. How many pounds of chemicals would be required assuming perfect mixing if 400 feet of 8-inch sewer were to be treated?

Known	Unknown
Concentration, mg/*L* = 100 mg/*L*	Chemical, lbs
Contact Time, min = 30 min	
Diameter, in = 8 in	
Length, ft = 400 ft	

Determine volume of sewer

$$\begin{aligned}\text{Volume, cu ft} &= (0.785)(\text{Diam, ft})^2(\text{Length,ft})\\ &= \frac{(0.785)(8\text{ in})^2(400\text{ ft})}{(12\text{ in/ft})^2}\\ &= 139.63\text{ cu ft}\end{aligned}$$

Volume, gal = (139.63 cu ft)(7.48 gal/cu ft)
= 1044.4 gal
= 0.0010444 MG

Calculate weight of water in sewer.

Weight, lbs = (Volume, gal)(8.34 lb/gal)
= (0.0010444 MG)(8.34 lb/gal)
= 0.0087 M lb

NOTE: 1 mg/*L* = 1 part/million parts = 1 lb/M lbs for water.

Calculate required pounds of chemicals.

$$100\text{ mg}/L = \frac{\text{Chemicals, lbs}}{\text{Water, M lbs}}$$

Chemicals, lbs = (100 mg/*L*)(Water, M lbs)
= (100 mg/*L*)(0.0087 M lb)
= 0.87 lbs

Order one pound of chemicals and pay the company if the chemicals work as claimed.

H. Excavation and Paving

24. A trench 3 feet wide, 8 feet deep and 70 feet long is to be filled with sand.
   a. How many cubic feet of sand required?
   b. How many cubic yards of sand?
   c. How many 5 cubic yard dump truck loads?
   d. How many tons of sand carried by each truck if sand weighs 144 lbs/cu ft?

Known	Unknown
Width, ft = 3 ft	a. Sand, cu ft
Depth, ft = 8 ft	b. Sand, cu yd
Length, ft = 70 ft	c. Number of trucks
Sand, lbs/cu ft = 144 lbs/cu ft	d. Truck load, tons

---

* *"Standard Methods" uses the term CHLORINE DEMAND when referring to stabilized water such as a domestic water supply and the term CHLORINATION REQUIREMENT when referring to wastewater.*

Find volume of trench and volume of sand.

$$\begin{aligned} \text{a. Volume, cu ft} &= (\text{Length, ft})(\text{Width, ft})(\text{Depth, ft}) \\ &= (70\text{ ft})(3\text{ ft})(8\text{ ft}) \\ &= 1680\text{ cu ft} \end{aligned}$$

$$\begin{aligned} \text{b. Volume, cu yd} &= \frac{(\text{Volume, cu ft})}{(27\text{ cu ft/cu yd})} \\ &= \frac{1680\text{ cu ft}}{27\text{ cu ft/cu yd}} \\ &= 62.22\text{ cu yd} \end{aligned}$$

Determine the number of 5 cu yd truck loads required.

$$\begin{aligned} \text{c. No. of truck loads} &= \frac{\text{Volume, cu yd}}{\text{Truck capacity, cu yd/load}} \\ &= \frac{62.22\text{ cu yd}}{5\text{ cu yd/load}} \\ &= \underline{\underline{12.44\text{ loads}}} \end{aligned}$$

Thirteen truck loads will be required.

Calculate the truck load in tons.

$$\begin{aligned} \text{d. Truck Load, tons} &= \frac{(\text{Truck Cap., cu yd})(\text{Sand, lbs/cu ft})(27\text{ cu ft/cu yd})}{(2000\text{ lbs/ton})} \\ &= \frac{(5\text{ cu yd})(144\text{ lbs/cu ft})(27\text{ cu ft/cu yd})}{2000\text{ lbs/ton}} \\ &= \underline{\underline{9.72\text{ tons}}} \end{aligned}$$

25. How many cubic yards of AC paving material will be required to pave over a trench 2400-feet long and 3-feet wide using a 3-inch deep patch?

Known	Unknown
Length, ft = 2400 ft	Paving, cu yards
Width, ft = 3 ft	
Depth, in = 3 in	

Find volume of paving in cu ft.

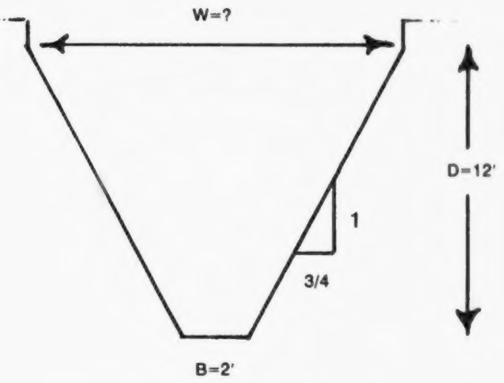
$$\begin{aligned} \text{Paving, cu ft} &= (\text{Length, (ft})(\text{Width, ft})(\text{Depth, ft}) \\ &= \frac{(2400\text{ ft})(3\text{ ft})(3\text{ in})}{(12\text{ in/ft})} \\ &= 1800\text{ cu ft} \end{aligned}$$

Calculate volume of paving in cu yd.

$$\begin{aligned} \text{Paving, cu yd} &= \frac{1800\text{ cu ft}}{27\text{ cu ft/cu yd}} \\ &= \underline{\underline{66.7\text{ cu yd}}} \end{aligned}$$

26. If a sewer trench is 2-feet wide at the bottom, 12 feet deep, and the walls are sloped at 3/4 horizontal to 1 vertical, how wide is the trench at the ground surface?

Known	Unknown
Trench base, ft = 2 ft	Trench width, ft at top
Trench depth, ft = 12 ft	
Trench slope, S = 3/4 ft horiz. to 1 ft. vert.	



Determine trench width at top.

$$\begin{aligned} \text{Slope, S} &= \frac{\text{Rise}}{\text{Run}} \\ &= \frac{1}{3/4} \\ &= 4/3 \end{aligned}$$

$$\begin{aligned} \text{Width, ft} &= \text{Base,ft} + \frac{(2\text{ sides})(\text{Depth, ft})}{\text{Slope}} \\ &= 2\text{ ft} + \frac{(2)(12\text{ ft})}{4/3} \\ &= 2\text{ ft} + \frac{(2)(12\text{ ft})(3)}{4} \\ &= 2\text{ ft} + 18\text{ ft} \\ &= \underline{\underline{20\text{ ft}}} \end{aligned}$$

27. Prepare a sewer grade (cut) sheet for a sewer laid on a 0.5% grade with the given stake elevations and an invert grade of 100.00 feet for station 0+00.

Station	Stake Elevation	Invert Grade	Cut
0+00	105.60	100.00	
0+50	106.12		
1+00	106.75		
1+50	107.37		
2+00	108.02		
2+50	108.41		
3+00	108.98		
3+50	109.22		
3+91	108.69		

To solve this problem, complete the above cut sheet by first calculating the invert grades.

$$\begin{aligned} \text{Grade, ft/ft} &= \frac{\text{Grade, \%}}{100\%} \\ &= \frac{0.5\%}{100\%} \\ &= 0.005\text{ ft/ft} \\ \text{or} \quad &= (0.005\text{ ft/ft})\left(\frac{100\text{ ft}}{100\text{ ft}}\right) \\ &= 0.5\text{ ft/100 ft} \end{aligned}$$

Since the grade is 0.5 ft per 100 ft, increase the invert grade by 0.25 ft for each 50 ft, or multiply the distance times the grade.

$$\begin{aligned}\text{Invert Grade, ft} &= 100.00\text{ ft} + (\text{Distance, ft})(\text{Grade, ft/ft})\\ &= 100.00\text{ ft} + (50\text{ ft})(0.005\text{ ft/ft})\\ &= 100.00\text{ ft} + 0.25\text{ ft} \quad = 100.25\text{ ft}\end{aligned}$$

Station

$$\begin{aligned}1+00 &= 100.00\text{ ft} + (100)(0.005) = 100.50\\ 1+50 &= 100.00\text{ ft} + (150)(0.005) = 100.75\\ 3+91 &= 100.00\text{ ft} + (391)(0.005) = 101.96\end{aligned}$$

To determine cut, subtract invert from stake elevation.

Station	Stake	–	Invert	=	Cut
0+00	105.50	–	100.00	=	5.60
0+50	106.12	–	100.25	=	5.87
1+00	106.75	–	100.50	=	6.25
3+91	108.69	–	101.96	=	6.73

Completed sewer cut sheet.

Station	Stake Elevation	Invert Grade	Cut
0+00	105.60	100.00	5.60
0+50	106.12	100.25	5.87
1+00	106.75	100.50	6.25
1+50	107.37	100.75	6.62
2+00	108.02	101.00	7.02
2+50	108.41	101.25	7.16
3+00	108.98	101.50	7.48
3+50	109.22	101.75	7.47
3+91	108.69	101.96	6.73

I. Electricity

28. A 12-volt battery operates a radio with a 4-ohm resistance. What amp fuse is necessary?

Known	Unknown
EMF, volts = 12 volts	Current, amps
Resist., ohms = 4 ohms	

Calculate the current, amps.

$$\begin{aligned}\text{Current, amps} &= \frac{\text{EMF, volts}}{\text{Resistance, ohms}}\\ &= \frac{12\text{ volts}}{4\text{ ohms}}\\ &= \underline{\underline{3\text{ amps}}}\end{aligned}$$

A three-amp fuse is necessary.

29. A 30-ohm resistor requires a current of 8 amps. How many watts will the resistor draw?

Known	Unknown
Resist., ohms = 30 ohms	Power, watts
Current, amps = 8 amps	

Calculate the power in watts.

$$\begin{aligned}\text{Power, watts} &= (\text{I, amps})^2\,(\text{R, ohms})\\ &= (8\text{ amps})^2\,(30\text{ ohms})\\ &= \underline{\underline{1920\text{ watts}}}\end{aligned}$$

30. A pump motor is supplied with 220 volts and draws 15 amps. What is the horsepower output of the motor if the power factor is 0.8 and the motor efficiency is 90%?

Known	Unknown
EMF, volts = 220 volts	Power, watts
Current, amps = 15 amps	Output, horsepower
Power factor = 0.8	
Efficiency, % = 90%	

Calculate the power in watts.

$$\begin{aligned}\text{P, watts} &= (\text{E, volts})(\text{I, amps})\\ &= (220\text{ volts})(15\text{ amps})\\ &= \underline{\underline{3{,}300\text{ watts}}}\end{aligned}$$

Calculate the output horsepower.

$$\begin{aligned}\text{Output, hp} &= \frac{(\text{P, watts})(\text{Power factor})(\text{Efficiency})}{746\text{ watts/hp}}\\ &= \frac{(3{,}300\text{ watts})(0.8))0.9)}{746\text{ watts/hp}}\\ &= \underline{\underline{3.18\text{ hp}}}\end{aligned}$$

Use a 3.5 horsepower motor.

J. Pumps

31. Determine the water horsepower delivered by a pump if the flow is 100 gallons per minute and the total dynamic head is 70 feet.

Known	Unknown
Flow, GPM = 100 GPM	Water hp, hp
TDH, ft = 70 ft	

Calculate water horsepower.

$$\begin{aligned}\text{Water hp} &= \frac{(\text{Q,GPM})(\text{TDH, ft})}{3960} = \frac{(\text{Q, cfs})(62.4\text{ lb/cu ft})(\text{H, ft})}{550\text{ ft-lb/sec-hp}}\\ &= \frac{(100\text{ GPM})(70\text{ ft})}{3960}\\ &= \underline{\underline{1.77\text{ hp}}}\end{aligned}$$

32. How efficient is a pump if the water horsepower is 1.77 hp and the brake horsepower is 2.50 hp?

Known	Unknown
Water hp = 1.77	Pump efficiency, %
Brake hp = 2.50 hp	

Calculate the pump efficiency.

$$\begin{aligned}\text{Pump efficiency, \%} &= \frac{(\text{Water hp})(100\%)}{\text{Brake hp}}\\ &= \frac{(1.77\text{ hp})(100\%)}{2.50\text{ hp}}\\ &= \underline{\underline{71\%}}\end{aligned}$$

33. If a pump motor draws 2000 watts and the water horsepower from the pump is 1.77 hp, what is the overall efficiency of the system?

Known	Unknown
Pump motor, watts = 2000 watts	Overall Eff., %
Water hp = 1.77 hp	

Find input horsepower.

$$\text{Input hp} = \frac{\text{Power drawn, watts}}{\text{746 watts/hp}}$$

$$= \frac{\text{2000 watts}}{\text{746 watts/hp}}$$

$$= \text{2.68 hp}$$

Calculate overall efficiency.

$$\text{Overall eff., \%} = \frac{\text{Output, hp}}{\text{Input, hp}}$$

$$= \frac{\text{(1.77 hp) 100\%}}{\text{2.68 hp}}$$

$$= \underline{\underline{66\%}}$$

34. A pump has a rated capacity of 500 GPM, develops a head of 120 feet, and has a power requirement of 20 hp when operating at 900 rpm. If the efficiency remains constant, what will be the operating characteristics if the speed increases to 1200 rpm?

Known	Unknown
Flow, GPM = 500 GPM	Q_n, GPM
Head, ft = 120 ft	H_n, GPM
Power, hp = 20 hp	P_n, GPM
N_r, rpm = 900 rpm	
N_n, rpm = 1200 rpm	

Calculate the new flow rate or capacity.

$$Q_n\text{, GPM} = \left(\frac{N_n}{N_r}\right) Q_r$$

$$= \left(\frac{\text{1200 rpm}}{\text{900 rpm}}\right) \text{500 GPM}$$

$$= \left(\frac{4}{3}\right) \text{500 GPM}$$

$$\underline{\underline{\text{667 GPM}}}$$

Calculate the new head.

$$H_n\text{, ft} = \left(\frac{N_n}{N_r}\right)^2 H_r$$

$$= \left(\frac{\text{1200 rpm}}{\text{900 rpm}}\right)^2 \text{120 ft}$$

$$= \left(\frac{4}{3}\right)^2 \text{120 ft}$$

$$= \underline{\underline{\text{213.3 ft}}}$$

Calculate the new power requirement.

$$P_n\text{, hp} = \left(\frac{N_n}{N_r}\right)^3 P_r$$

$$= \left(\frac{\text{1200 rpm}}{\text{900 rpm}}\right)^3 \text{20 hp}$$

$$= \left(\frac{4}{3}\right)^3 \text{20 hp}$$

$$= \underline{\underline{\text{47.4 hp}}}$$

35. The rate at which a wet well fills can be used to calibrate a flow meter. The same procedure can be used to determine the capacity of a pump. Determine the pump capacity in GPM if an 8-foot long and 6-foot wide wet well is lowered 4 feet in 5 minutes. Assume no additional water flows into the wet well.

Known	Unknown
Length, ft = 8 ft	Flow, GPM
Width, ft = 6 ft	
Depth, ft = 4 ft	
Time, min = 5 min	

Determine volume of water pumped.

$$\text{Volume, cu ft} = \text{(Length, ft)(Width, ft)(Depth, ft)}$$

$$= \text{(8ft)(6ft)(4ft)}$$

$$= \text{192 cu ft}$$

$$\text{Volume, gal} = \text{(192 cu ft)(7.48gal/cu ft)}$$

$$= \text{1436 gal}$$

Calculate pumping rate.

$$\text{Flow, GPM} = \frac{\text{Volume, gal}}{\text{Time, min}}$$

$$= \frac{\text{1436 gal}}{\text{5 min}}$$

$$= \underline{\underline{\text{287 GPM}}}$$

36. Water is flowing into a wet well at a rate of 342 GPM. The level of the wet well is rising at a rate of 28 GPM. What is the pump capacity under these conditions?

Known	Unknown
Inflow, GPM = 342 GPM	Pump, GPM
Rise, GPM = 28 GPM	

Determine pump capacity.

$$\text{Inflow} = \text{Outflow} \pm \text{Storage}$$

$$\text{Inflow, GPM} = \text{Pump, GPM} + \text{Rise, GPM}$$

or

$$\text{Pump, GPM} = \text{Inflow GPM} - \text{Rise, GPM}$$

$$= \text{342 GPM} - \text{28 GPM}$$

$$= \underline{\underline{\text{314 GPM}}}$$

37. A lift station receives wastewater from a 24-inch intercepting sewer with a capacity of 5 MGD. The elevation of the sewer invert entering the wet well is 51.80 feet. The elevation of lowest manhole lid on the intercepting sewer is 75.20 feet and the elevation of the lowest home plumbing fixture that could overflow and cause damage is 76.50 feet. The slope of the intercepting sewer is 1.5 ft/1000 ft. If the lift station pumps fail or there is a power outage, how much time is available to get the lift station back on the line if the inflow is 2.5 MGD?

Known	Unknown
Diameter, in = 24 in	Time, hour
Sewer capacity, MGD = 5 MGD	
Sewer flow, MGD = 2.5 MGD	
Elev. of invert to L.S. = 51.80 ft	
Elev. of MH lid = 75.20 ft	
Elev. of fixture = 76.50 ft	
Sewer Slope = 1.5 ft/1000 ft	

PROCEDURE

1. Calculate the storage capacity in the intercepting sewer when it is flowing at 2.5 MGD. Use only the capacity in the sewer between the wet well and the lowest manhole lid. A safety factor will be provided by any connecting sewers and a portion of the sewer whose crown elevation is above the lowest manhole lid but whose invert is below the elevation of the lid.
2. Calculate the time to fill the intercepting sewer by dividing the flow into the storage capacity.

Determine elevation at crown of sewer entering wet well.

Elevation of sewer invert = 51.80 ft
Diameter of sewer = 2.00 ft
Elevation of crown of sewer = 53.80 ft

Calculate the elevation of vertical distance the water can rise before overflowing from the lowest manhole lid. Use crown of sewer rather than water surface at well because the empty portion of the sewer is the space or storage capacity that will be filled with water.

Elevation of manhole lid = 75.20 ft
Elevation of crown of sewer = 53.80 ft
Difference in elevation = 21.40 ft

Use 21 feet with a 0.4 foot additional safety factor.

Estimate length of sewer that could be filled before the lowest manhole starts overflowing.

$$\text{Length of sewer, ft} = \frac{\text{Diff. in elev., ft}}{\text{Sewer slope, ft/ft}}$$

$$= \frac{21.00\text{ ft}}{1.5\text{ ft}/1000\text{ ft}}$$

$$= (14\text{ ft})(1000)$$

$$= 14{,}000\text{ ft}$$

NOTE: If slope is not 1.5 ft/1000 ft over entire 14,000-foot section, length will have to be recalculated on basis of actual slopes and lengths until difference in elevation is reached.

Calculate the cross-sectional area of the sewer.

$$\text{Area, sq ft} = (0.785)(\text{Diameter, ft})^2$$

$$= (0.785)(2\text{ ft})^2$$

$$= 3.14\text{ sq ft}$$

Determine volume of 24-inch sewer 14,000 feet long.

$$\text{Volume cu ft} = (\text{Area, sq ft})(\text{Length, ft})$$

$$= (3.14\text{ sq ft})(14{,}000\text{ ft})$$

$$= 43{,}982\text{ cu ft}$$

Note: If 24-inch sewer is not 14,000 feet long, volume will have to be calculated on basis of lengths and diameters of sewer in 14,000-foot section.

What portion of volume is available for storage? If flow is 2.5 MGD and capacity is 5.0 MGD, then sewer is flowing half full.

$$\frac{\text{Actual flow}}{\text{Capacity}} = \frac{2.5\text{ MGD}}{5.0\text{ MGD}}$$

$$= \tfrac{1}{2}\text{ full}$$

Therefore, ½ volume of sewer is available for storage.

$$\text{Storage volume, cu ft} = (\tfrac{1}{2})(\text{Volume, cu ft})$$

$$= (\tfrac{1}{2})(43{,}982\text{ cu ft})$$

$$= 21{,}991\text{ cu ft}$$

Estimate time to fill sewer before manhole overflows.

$$\text{Time, hr} = \frac{(\text{Storage volume, cu ft})(7.5\text{ gal/cu ft})(24\text{ hr/day})}{(\text{Flow, gal/day})}$$

$$= \frac{(21{,}991\text{ cu ft})(7.5\text{ gal/cu ft})(24\text{ hr/day})}{2{,}500{,}000\text{ gal/day}}$$

$$= 1.58\text{ hr or }1\text{ hr} + 0.58\text{ hr }(60\text{ min/hr})$$

$$= \underline{\underline{1\text{ hr }35\text{ min}}}$$

38. In the previous problem (number 37) we estimated a time of 1 hour and 35 minutes would be available before the lowest manhole would start overflowing. In actual practice we would watch the rate of rise of the water backing up to estimate how much time is available before the manhole would overflow. Estimate the expected rate of rise and calculate the actual rate of rise if water is rising 1.0 foot in 5 minutes.

Known	Unknown
From problem 34	Estimated rise, ft/min
Distance, ft = 21.00 ft	Actual rise, ft/min
Time, hr = 1.58 hr	
= 1 hr 35 min	
This problem	
Distance, ft = 1.0 ft	
Time, min = 5 min	

Calculate estimated rise.

$$\text{Est. rise, ft/min} = \frac{\text{Distance, ft}}{\text{Time, min}}$$

$$= \frac{21.0\text{ ft}}{(1.58\text{ hr})(60\text{ min/hr})}$$

$$= 0.22\text{ ft/min}$$

How long would we estimate it takes for the water to rise 1 foot?

$$\text{Est. rise, min/ft} = \frac{\text{Distance, ft}}{\text{Est. rise, ft/min}}$$

$$= \frac{1\text{ ft}}{0.22\text{ ft/min}}$$

$$= \underline{\underline{4.54}}\text{ min to rise 1 ft}$$

What is the actual rate of rise?

$$\text{Actual rise, ft/min} = \frac{\text{Distance, ft}}{\text{Time, min}}$$

$$= \frac{1.0 \text{ ft}}{5 \text{ min}}$$

$$= \underline{\underline{0.2 \text{ ft/min}}}$$

Note: Since the actual time for the water to rise 1 foot is 5 minutes and we estimated 4.5 minutes, we'll have a little longer than our estimated time of 1 hour and 35 minutes to get the lift station back on the line before the lowest manhole starts to overflow. Continue to watch the actual rate of rise for any changes.

K. Ventilation

39. What capacity blower (CFM) is required to ventilate a manhole 48 inches in diameter and 17-feet deep with 15 air changes per hour or one air change every 4 minutes?

Known	Unknown
MH Diameter, in = 48 in	Blower Capacity, CFM
MH Depth, ft = 17 ft	
Air change, min = 4 min	

Determine volume of manhole.

$$\text{MH Volume, cu ft} = (\text{Area, sq ft})(\text{Depth, ft}) \qquad \text{Area} = 0.785\ D^2$$

$$= (0.785)(4 \text{ ft})^2(17 \text{ ft})$$

$$= 213.6 \text{ cu ft}$$

Calculate blower capacity.

$$\text{Blower Capacity, CFM} = \frac{\text{MH Volume, cu ft}}{\text{Air Change, min}}$$

$$= \frac{213.6 \text{ cu ft}}{4 \text{ min}}$$

$$= 53.4 \text{ cu ft/min}$$

$$\text{or at least} \quad \underline{\underline{55 \text{ CFM}}}$$

L. Costs

40. Estimate the total cost and cost per linear foot of a sanitary sewer construction project. The project consists of 1550 lineal feet of 10-inch VCP with four manholes equally spaced. The average depth of the trench is 9 feet and the average width is 3 feet (including excavation for manholes). Estimated costs are as follows:

Excavation and backfill	$30.00 per linear foot
Pipe cost	$ 5.00 per linear foot
AC paving	$ 4.00 per square foot
Manholes, completed	$1500.00 each

Known	Unknown
Costs given above	Total Cost, $
Length, ft = 1550 ft	Cost/ft, $/ft
Diameter, in = 10 in	
Depth, ft = 9 ft	
Width, ft = 3 ft	

Determine excavation and backfill cost.

$$\text{Cost, \$} = (\text{Cost, \$/ft})(\text{Length, ft})$$

$$= (\$30.00/\text{ft})(1550 \text{ ft})$$

$$= \$46{,}500$$

Determine pipe cost.

$$\text{Cost, \$} = (\text{Pipe, cost, \$/ft})(\text{Length, ft})$$

$$= (\$5.00/\text{ft})(1550 \text{ ft})$$

$$= \$7{,}750.00$$

Determine paving cost.

$$\text{Cost, \$} = (\text{Paving, cost, \$/sq ft})(\text{Length, ft})(\text{Width, ft})$$

$$= (\$4.00/\text{sq ft})(1550 \text{ ft})(3 \text{ ft})$$

$$= \$18{,}600.00$$

Determine manhole cost.

$$\text{Cost, \$} = (\text{MH cost, \$/MH})(\text{Number of MH})$$

$$= (\$1500/\text{MH})(4 \text{ MH})$$

$$= \$6000.00$$

Determine total cost of project.

Exc. and backfill	= $46,500.00
Pipe	= 7,750.00
Paving	= 18,600.00
MH	= 6,000.00
Total Cost	= $78,850.00

Determine cost per linear foot.

$$\text{Cost, \$/ft} = \frac{\text{Total Cost, \$}}{\text{Length, ft}}$$

$$= \frac{\$78{,}850.00}{1550 \text{ ft}}$$

$$= \underline{\underline{\$50.87/\text{ft}}}$$

$$\text{or} \quad = \$51/\text{ft}$$

41. A review of previous records indicated that a certain repair job could be completed by a crew of two workers in 20 hours. How long would it take a crew of five workers to complete a similar job and what would be the labor costs at $5.00 per hour?

Known	Unknown
Two workers can do job in 20 hours.	Time for 5 workers
Labor = $10.00/hour	Labor costs

Determine worker-hours to do the job.

$$\text{Time, worker-hours} = (\text{Number of workers})(\text{Time, hours})$$

$$= (2 \text{ workers})(20 \text{ hours})$$

$$= 40 \text{ worker-hours}$$

Calculate time for 5 workers to do job.

$$\text{Time, hours} = \frac{\text{Time, worker-hours}}{\text{Number of workers}}$$

$$= \frac{40 \text{ worker-hours}}{5 \text{ workers}}$$

$$= \underline{\underline{8 \text{ hours}}}$$

Estimate labor costs.

$$\text{Labor costs, \$} = (\text{Time, worker-hours})(\text{Labor, \$/worker-hour})$$

$$= (40 \text{ worker-hours})(\$10/\text{worker-hour})$$

$$= \underline{\underline{\$400}}$$

M. Performance Indicators

42. A collection system manager wishes to determine performance indicators and performance ratings for both the city's sewer system and lift stations. Annual costs for operating and maintaining the sewer system are $150,000 per year and $50,000 per year for the lift stations. The city serves a population of 50,000 people with 150 miles of sewers and 20 lift stations. Last year there were 15 sewer line stoppages which caused flooding and one lift station failure which caused flooding. The lift station consumed 2.4 million kilowatt hours last year. Assume a sewer line standard of 90 and a lift station standard of 1000.

SEWERS

Known		Unknown
Length of sewers, mi	= 150 mi	1. Performance Indicator
Annual costs, $/yr	= $15,000/yr	2. Performance Rating
Number of stoppages	= 15/yr	
Assumed standard	= 90	

1. Calculate the Performance Indicator for the sewer lines.

$$\text{Performance Indicator} = (\text{Costs, \$/mi})(\text{Stoppages, number/mi})$$

$$= \frac{(\$150{,}000)(15 \text{ stoppages})}{(150 \text{ mi})(150 \text{ mi})}$$

$$= \underline{\underline{100}}$$

2. Calculate the Performance Rating for the sewer lines.

$$\text{Performance Rating} = \frac{(\text{Standard})(100\%)}{\text{Performance Indicator}}$$

$$= \frac{(90)(100\%)}{100}$$

$$= \underline{\underline{90\%}}$$

LIFT STATIONS

Known		Unknown
Number of lift stations	= 20	1. Performance Indicator
Annual costs, $/yr	= $50,000/yr	2. Performance Rating
Number of failures	= 1/yr	
Energy consumed, mkwh/yr	= 2.4 mkwh/yr	
Assumed standard	= 1000	

1. Calculate the Performance Indicator for the lift stations.

$$\text{Performance Indicator} = \frac{(\text{Costs, \$/station})(\text{Failures, number/station})}{\text{Energy Consumed, mkwh/station}}$$

$$= \frac{(\$50{,}000/20)(1/20)}{(2.4/20)}$$

$$= \frac{(2{,}500)(0.05)}{0.12}$$

$$= \underline{\underline{1042}}$$

$$\text{Performance Rating} = \frac{(\text{Standard})(100\%)}{\text{Performance Indicator}}$$

$$= \frac{(1000)(100\%)}{1042}$$

$$= \underline{\underline{96\%}}$$

A.13 ADDITIONAL READING

1. *MATHEMATICS FOR WATER AND WASTEWATER TREATMENT PLANT OPERATORS*, Book 1 — Fundamentals and Book 2 — Advanced, by Joanne Kirkpatrick, Ann Arbor Science Publishers, Inc./The Butterworth Group, 10 Tower Office Park, Woburn, MA 01801. Price, $22.50 each.
2. *AMERICAN NATIONAL STANDARD METRIC PRACTICE*, American National Standards Institute, 1430 Broadway, New York, New York 10008. Price $4.00.

A.14 PRACTICE PROBLEMS

1. Estimate the number of people contributing to a flow of 400,000 gallons per day in an 8-inch sewer. Assume a population flow equivalent of
   a. 100 gpcd
   b. 85 gpcd.
2. A large cannery discharges 8 MGD during the peak canning season. What is the typical population equivalent using 100 gpcd?
3. A subdivision serves 1500 people. What is the expected average daily flow in MGD assuming 100 gpcd?
4. A colored dye is dumped into a manhole. The dye first appears 4 minutes later in a manhole 750 feet downstream and disappears 6 minutes after first dumped into manhole. Estimate the velocity of flow in the sewer in
   a. ft/min
   b. ft/sec.
5. A float required 3 minutes and 28 seconds to travel 428 feet between two manholes. Estimate the velocity of the wastewater in the sewer assuming the surface velocity (float velocity) is 12 percent higher than the average velocity.
6. Estimate the flow in a 15-inch sewer flowing full if the average velocity is 2.6 ft/sec.
   a. cfs
   b. MGD
   c. GPM
7. Calculate the flow in a 6-inch sewer flowing half full when the average velocity is 2.3 ft/sec.
   a. cfs
   b. MGD
8. An 8-inch sewer carries a flow of 0.5 MGD when flowing full. What is the average velocity?
9. A sewer must carry a maximum flow of 1 MGD at a velocity of 2 ft/sec. What is the diameter? Select the next smaller nominal diameter so the actual flow will exceed 2 ft/sec and assume adequate grade is available to achieve the necessary velocity.

10. What is the average daily flow during August for a lift station given the following flow totalizer readings:

8:00 a.m. August 1 2,023,761,405 gallons
8:00 a.m. September 1 2,232,109,478 gallons
There are 31 days in August.

11. Estimate the average daily flow on Mondays for a lift station with the following readings:

Date	Flow, MG
Aug. 4	1.75
Aug. 11	1.78
Aug. 18	1.63
Aug. 25	1.72

12. A piece of pipe is 17 feet long and is to be cut into 5 equal pieces. Each piece will be ___ ft ___ inches long.

13. A piece of pipe is 11 feet, 6 inches long and is to be cut into 4 equal pieces. Each piece will be ___ ft ___ inches long.

14. One side of the grounds for a lift station is 100 feet long. How many trees will be required if the trees are to be 25 feet apart with a tree at each end? *HINT:* Draw a sketch.

15. How many feet will a 12-inch sewer rise in 420 feet when laid on a grade of 0.009?

16. A trench drops 13 feet in 828 feet, what is the grade in ft/ft and in percent?

17. How many feet will a 6-inch sewer drop in 385 feet when laid on a 0.7% grade?

18. Determine the slope on a 10-inch sewer that is 367 feet long if the invert elevation at the downstream manhole is 77.23 feet and upstream invert elevation is 81.39 feet.

19. An 8-inch sewer has been televised and the footage meter between two manholes indicates the distance is 381 feet. An actual field measurement verifies the distance shown on the plans as 392 feet.
    a. What is the percent error in the length?
    b. If the TV camera was pulled from the upstream to the downstream manhole, what is the distance from each manhole to a protruding tap at a distance of 238 feet?

20. A 6-inch sewer 383 feet long is given a water leak test. The downstream manhole is plugged where the line enters the manhole and there are no service lines connected to the test line. At 9:00 a.m. on Thursday morning, the 36-inch upstream manhole was filled to the bottom of the cone. At 9:00 a.m. on Friday morning, the water had dropped 3 feet 8 inches. Calculate the leakage from the sewer in terms of gallons per day per inch of sewer diameter per mile of sewer.

21. A section of sewer in a swampy area is going to be televised in an attempt to locate and identify the causes of excessive infiltration. The distance to be televised measures 2-13/16 inch and the scale is 1 inch equals 800 feet. How long (in feet) is the line to be televised?

22. How many square feet surface area in a maintenance corporation yard that measures 2¾ inch by 5⅜ inch on a drawing whose scale is 1 inch equals 40 feet?

23. A new manhole has been installed 254 feet from an existing manhole. How far would this new manhole be located from the old manhole on a map with a scale of 1 inch equals 40 feet?

24. Estimate the chlorine demand of a wastewater if the chlorinator is dosing at a rate of 20 mg/*L* and a residual of 0.4 mg/*L* of chlorine remains in the wastewater 30 minutes later.

25. If a wastewater is to be dosed at a rate of 10 mg/*L* and the flow is 2 MGD, what should be the chlorinator setting in pounds of chlorine per day?

26. A chlorinator is set to dose at a rate of 100 pounds of chlorine per day. What is the dose in mg/*L* when the flow is 0.8 MGD?

27. How many pounds of chemicals are required for root control if a concentration of 300 mg/*L* is recommended by the manufacturer to dose a 6-inch sewer 326 feet long?

28. Ten pounds of chemicals could produce what concentration (mg/*L*) if perfectly mixed in a 10-inch sewer 407 feet long?

29. A trench 2.5 feet wide, 6.5 feet deep and 65 feet long is to be filled with select backfill.
    a. How many cubic feet of backfill required?
    b. How many cubic yards of backfill?
    c. How many 5-cubic yard dump truck loads?
    d. How many tons of backfill if the backfill weighs 130 lbs/cu ft?

30. How many cubic yards of AC paving material will be required to pave a maintenance yard 100 feet wide and 200 feet long if the paving material is to be 4 inches thick?

31. How wide is a sewer trench at the top if the trench is 3-feet wide at the bottom, 9 feet deep, and the walls are sloped at 1-foot horizontal to 1-foot vertical?

32. Prepare a sewer grade (cut) sheet for a sewer laid on a 0.7% grade with the given stake elevations and invert grade.

Station	Stake Elevation	Invert Grade	Cut
0+00	57.28	50.00	____
0+50	57.91	____	____
1+00	58.13	____	____
1+50	58.55	____	____
2+00	59.67	____	____
2+48	60.03	____	____

33. A 12-volt battery operates a radio with a 3.5-ohm resistance. What amp fuse is necessary?

34. A pump motor is supplied with 440 volts and draws 35 amps. What is the horsepower output of the motor if the power factor is 0.85 and the motor efficiency is 89%?

35. A 40-ohm resistor requires a current of 11 amps. How many watts will the resistor draw?

36. Determine the water horsepower delivered by a pump if the flow is 500 GPM and the total dynamic head is 58 feet.

37. What is the total dynamic head that a pump can overcome when the flow is 2 cfs (cubic feet per second) and the delivered water horsepower is 10 horsepower?

38. What flow (GPM) could a 6 horsepower pump deliver against a total dynamic head (TDH) of 48 feet under these flow conditions? NOTE: TDH depends on flow and increases with flow. Usually a flow is known, the TDH is determined, and a pump to meet these requirements is selected.

39. How efficient is a pump if the brake horsepower is 8 hp and the water horsepower is 5.8 hp?

40. If a pump motor draws 3800 watts and the water horsepower from the pump is 3.5 hp, what is the overall efficiency of the system?

41. A variable-speed pump delivers 500 GPM at a speed of 1200 rpm. What should be the speed to deliver 500 GPM?

42. Estimate the flow into a wet well 5-feet wide and 8-feet long if the level rises 3.5 feet in 6 minutes.

43. Estimate the pumping rate of a pump when water is flowing into a wet well at 500 GPM and the wet well water level is dropping 0.8 feet in 3 minutes. The wet well is 5 feet by 5 feet.

44. Estimate the total cost and cost per linear foot of a sanitary sewer construction project. The project consists of 378 feet of 6-inch sewer and one manhole. Costs are estimated as follows:

Excavation and backfill	$ 12.00 per linear foot
Pipe cost	$ 2.00 per linear foot
Manhole, complete	$650.00 each

45. Estimate the time for a four-operator crew to complete a particular job and the labor costs are $6 per hour. Previous records indicate that the job could be completed by a crew of three operators in 36 hours. Also estimate the total cost of labor.

46. The temperature of wastewater in a sewer is reported as 12°C. What is the temperature in degrees Fahrenheit?

47. The temperature of wastewater is measured as 75°F. What is the temperature in degrees Celsius (Centigrade)?

48. Determine the performance indicators and performance ratings for both the sewer lines and lift stations described in this problem. Annual costs for operating and maintaining the 176 mile sewer system are $176,392 per year and $39,186 per year for the 17 lift stations. Last year there were 23 sewer line stoppages which caused flooding and two lift station failures which caused flooding. The lift station consumed 0.572 million kilowatt hours last year. Assume a sewer line standard of 120 and a lift station standard of 6000.

A.15 ANSWERS TO PRACTICE PROBLEMS

1. a. 4000 persons
   b. 4706 persons
2. 80,000 persons
3. 0.150 MGD
4. a. 150 ft/min
   b. 2.5 ft/sec
5. 1.81 ft/sec
6. a. 3.19 cfs
   b. 2.06 MGD
   c. 1433 GPM
7. a. 0.23 cfs
   b. 0.15 MGD
8. 2.2 ft/sec
9. 12 in
10. 6.72 MGD
11. 1.72 MGD
12. 3 ft 4 13/16 in
13. 2 ft 10 1/2 in
14. 5 trees
15. 3.78 ft
16. 0.0157 ft/ft or 1.57%
17. 2.70 ft
18. 0.0113 ft/ft or 1.13%
19. a. 2.8%
    b. 245 ft from upper
       147 ft from lower
20. 446 gpd/in/mi
21. 2250 ft
22. 23,650 sq ft
23. 6 3/8 in
24. 19.6 mg/*L*
25. 170 lbs/day
26. 15 mg/*L*
27. 1.2 lbs
28. 722 mg/*L*
29. a. 1056 cu ft
    b. 39 cu yd
    c. 8 truck loads
    d. 68.6 tons
30. 247 cu yds

31. 21 ft

32.

Station	Invert Grade	Cut
0+00	50.00	7.28
0+50	50.35	7.56
1+00	50.70	7.43
1+50	51.05	7.50
2+00	51.40	8.27
2+48	51.74	8.29

33. 3.5 amps

34. 15.6 hp

35. 4840 watts

36. 7.32 hp

37. 44 ft

38. 495 GPM

39. 72.5%

40. 68.7%

41. 1320 rpm

42. 175 GPM

43. 550 GPM

44. $5942
$15.72/ft

45. 27 hours
$648

46. 53.6°C

47. 23.9°C

48. Sewers
PI = 131
PR = 92%

Lift Stations
PI = 8095
PR = 74%

OPERATION AND MAINTENANCE

OF WASTEWATER COLLECTION SYSTEMS

Volume I

SUBJECT INDEX

A

ABSP, 61
ACP, 61
ASTM, 92, 93
Access to
  excavations, 377
  trenches, 72
Acrylonitrile butadiene styrene pipe, 61
Activated carbon towers, 348
Aerobic, 347
Air gap device, 276, 279
Air jumpers, 52, 55
Air plugs, 97
Air shores, 382, 384
Air, sulfide control, 349
Air testing, 94-101, 183, 267
Alarm, atmospheric, 137, 142
Alarm, set points, 144
Alignment, sewers, 60
American Society for Testing and Materials, 92, 93
Anaerobic, 345
Anderson, Blake, 349
Angle of repose, 376
Appurtenances
  collection system, 42-44, 87
  construction inspection, 94
  inspection and testing, 93
  sewer, 87
Area, partly filled pipe, 40
Arithmetic, 471
Arrival at job site, 270
Arrows, traffic, 117, 123
As-built plans, 104, 192, 401
Asbestos cement pipe, 61
Assignment of jobs, 370, 395, 401
Atmosphere, explosive, 150
Atmospheric alarm unit, 137, 142
Atmospheric hazards, 132
Average daily flow, 37, 38

B

BOD, 346
Backfill,
  compaction, 89
  completing, 89
  imported, 88
  inspection, 94
  inspection and testing, 94
  materials, 88
  native, 88
  pipe, 399, 403
  pipe protection, 89
  placement, 89, 90
Backflow preventers, 44, 47
Backhoes, 71
Bags, 265, 268, 303, 340
Balling
  advantages, 268
  application, 265-267, 269, 273
  crews, 273
  equipment, 268, 273, 282
  frequency, 273
  limitations, 268
  manpower, 273
  operation, 281, 283
  precautions, 273, 287
  records, 270, 287
  safety, 281, 287
  sand trap, 284
  set up, 281
  use, 265-267, 269, 273
Band couplings, 403
Barrel, pipe, 264
Barricades, 117, 118
Batter board, 82
Bedding
  classes, 84
  construction, 85
  inspection and testing, 93
  materials, 85
  pipe, 82, 84, 93, 181, 370, 399, 403
Bell and spigot pipe, 62, 86
Bench mark, 55
Biochemical oxygen demand, 346
Birch, Silas R., 92, 108
Blockages
  See Stoppages
Blower, 144, 148
Blowing toilets, 294
Body resistance and currents, 157
Boring machines, 71
Borings, 71
Bottoms, manhole repair, 415
Braces, shoring, 375, 376
Branch sewer cleanout, 48
Branch sewers, 42, 43
Broken rods, 326, 327
Bucket bail, 315
Bucket machines
  accessories, 310
  advantages, 268
  application, 265, 267, 269, 306
  bucket bail, 315
  cable scroll, 334
  communication, 314
  crews, 308
  equipment, 268, 308

Bucket machines (continued)
  level wind system, 334
  limitations, 268
  loading chutes, 316
  maintenance, 333
  manpower, 308
  operation, 312, 315
  porcupine tool, 314
  precautions, 316
  records, 270, 317
  safety, 314, 316
  set up, 309, 314
  use, 265, 267, 269, 306
  working machine, 311
Bugs, 135
Building sewers
  air testing, 100
  cleanout, 48, 49
  connection, 48, 50
  definition, 37
  location, 81, 104, 107
  testing, 93
  typical, 42, 43
  vent trap, 47, 48
Building tap, 48

C

CIP, 61
CMP, 61
Cable scroll, 334
Cable strain relief, 202
Calcium hydroxide, 349
Calibration, atmospheric alarm, 142, 144
Cast iron pipe, 61, 203
Catalytic sensing elements, 143
Causes of problems, 374
Cave-ins, 369, 375
Certification, operation, 9
Channel corrections, manhole, 416
Chemicals
  applications, 265, 266, 269, 338, 340, 341
  cautions, 336
  chlorine, 348
  cleaning, 338
  clothing, protective, 342
  corrosion, 344
  costs, 339
  EPA Pesticides Regulation Division, 339
  effectiveness, 341
  evaluation, 341
  first aid, 342
  flooding, application, 341
  foaming, application, 341
  grease, 342
  how to select, 338, 339
  hydrogen peroxide, 348
  hydrogen sulfide, 346, 347
  insects, 344
  labels, 163-169
  lime, 349
  maintenance, 338
  odors, 343
  operation, 338
  oxygen, 349
  precautions, 338, 341
  protective clothing, 342
  pure oxygen, 349
  reuse of chemicals, 341
  rodents, 344
  roots, 340
  sewers, 265, 266, 269
  sodium hydroxide, 349
  spraying, application, 341
  TV line first, 341
  test section, 339
  uses, 265, 266, 269, 338
Chlorine, 348
Civil service exams, 9
Clamshell trenchers, 71
Classes of sewer bedding, 84
Classification of manhole hazards, 124
Clean up after
  clearing stoppages, 293, 326
  construction, 91
  rodding, 326
  sealing, 346
Cleaning equipment maintenance, 333
Cleaning, manholes, vacuum device, 291
Cleaning sewers
  bags, 265, 303
  balls, 265-267, 273
  bucket machines, 265, 267, 306
  flushing, 265, 267, 294
  hand rods, 265, 266, 269, 329
  high velocity cleaners, 265-267, 287
  hydraulic methods, 265
  jets, 265-267
  kite, 265-267, 303
  mechanical methods, 265, 306
  methods, 265
  objectives, 264
  parachutes, 265
  poly pigs, 303
  porcupine, 307
  power rodders, 265, 266, 317
  rodding, 265, 266, 317
  scooters, 265-267, 297
  selection of method, 268
  sewer balls, 265-267
  swab, 307, 313
  tires, 265, 285, 303
Cleaning sewers, hydraulic, 273
Clearing sewers,
  also see Mechanical sewer cleaning
  chemicals, 265, 266
Cleanout, 48, 49, 51
Cleanouts, 399
Cleanouts, construction, 88
Closed circuit television inspection, 191
Clothing, protective, 146
Codes for TV inspection, 242-244
Coil rodders, 319
Cold weather maintenance, 336
Collection systems
  appurtenances, 44, 87, 93
  cleaning, 265, 269, 273
  combined, 36
  complaints, 17, 264
  confined spaces, 8, 124
  construction, 17, 36, 71, 92
  corrosion, 36
  definition, 4
  design, 36, 52, 181, 369
  doctor, diagnose system problems, 19
  drawing, 5
  emergency conditions, 63
  excavation, 71
  failures, 4
  funding, 6

Collection systems (continued)
  grease, 264, 266
  hydraulic cleaning, 265, 269, 273
  inspection, 18, 19, 36, 92, 181
  layout, 5
  leaks, 17, 94, 101, 181
  line and grade, 52, 57, 60
  maintenance, 63
    also see Maintenance
  manholes, 63, 87, 93
  mechanical cleaning, 265, 307
  odors, 17, 18, 36, 63, 264
  operation and maintenance, 4, 9, 16, 63
  operator jobs, 7
  operator pay, 8
  operator recognition, 7
  operator training, 4, 9
  problems, 181
  purpose, 36
  repair, 55
  roots, 264, 266
  routing traffic, 116
  safety, 116, 124, 135, 146, 148, 153, 160, 161
  sanitary, 36
  sealing, 403
  sewer-use ordinance, 182, 346
  shoring, 71, 72, 375
  sketch, 5
  stoppages, 6, 264, 266
  storm, 36
  sulfide control, 63
  testing, 94, 101, 181
  traffic safety, 116
  training, 4, 9
Combined collection systems, 36
Combustible gas tester, 137
Commands
  balling, 284, 286
  bucket machines, 314
  high velocity cleaner, 286
  TV inspection, 203
Communication, design, 65
Compaction,
  backfill, 88-91, 399, 403
  inspection, 94
  measurement, 91
  mechanical, 90, 91
  water, 89-91
Compaction of backfill, 89
Complaints, 17, 264
Components, collection systems, 42, 43
Concrete, inspection and testing, 93
Cones, traffic, 116
Confined space
  definition, 124
  entry form, 149
  procedures, 148-153
  responsibility, 153
Confined spaces, 8, 164
Construction
  appurtenance inspection, 94
  appurtenances, 87
  backfill, 82, 88, 89
  backfilling and compaction, 99
  bedding, 82, 85
  cleanouts, 88
  compaction, 88-91
  controls, 78-82
  equipment, 71
  excavation, 71
  grade pole, 80, 81
  inspection, 18, 92-94
  inspection and testing, 92
  inspection procedures, 93
  inspector, 92
  manholes, 53, 87, 88, 94
  materials inspection, 92
  new, 364, 418
  pipe damage, 17, 264
  pipe laying, 85
  problems caused by, 181, 369
  records, 104-108
  reports, 104-106
  sewers, 65, 70
  shoring, 71-78
  stoppages, 264
  vertical risers, 51
Contacting public, 227, 374, 394
Continuous rodders, 319, 328, 335
Contractors
  construction, 17, 36, 65
  inspection, 18
  sewer cleaning, 7
Controls, construction, 78-82
Corrosion, 36, 61, 63
Corrugated metal pipe, 61
Cost effective, 17, 183
Costs
  chemicals, 339
  collection system, 16, 18
Couplings, band, pipe, 403
Cover, raising, manhole, 410-414
CP, 62
Crib shoring, 387
Cross braces, shoring, 376
Cross connections, 6
Cut sheet, sewer, 80
Cutters, pipe, 398, 399
Cutting pavement, 402
Cylinder, shoring, 386

D

DIP, 61
Daily reports, 104
Damages to sewers, 370
Dangerous air contamination, 131
Data, recording, 205
Debris, 267, 269
Defensive driving, 115, 116
Deflection
  pipe, 61, 62
  test, 102, 103
Degradation, 347
Depletion of oxygen, 132
Depth, sewers, 60
Description, manhole hazards, 124
Design
  collection systems, 36, 52, 181, 345, 367
  communication, 65
  depth, 60
  field investigations, 63
  field surveys, 52, 55, 57
  flows, 37, 57
  items influencing maintenance, 63
  layout, 43, 52
  location and alignment, 60
  maintenance, 63
  manhole materials, 63

Design (continued)
  office study, 63
  pipe joints, 62
  pipe materials, 61
  plan and profile, 63, 64
  review, 63
  slope and size, 57
  velocity and flow, 59
Design period, 37
Directions
  balling, 284-286
  bucket machines, 314
  high velocity cleaners, 286
  TV inspection, 203
Diseases, 17, 133
Disinfectants, 293
Dissolved sulfide, 347
Ditches, sewer, 17
Doctor, diagnose system problems, 19, 264
Dragline trencher, 71
Drainage, surface, 132
Drop, joint, 217, 218
Drowning, 135
Ductile iron pipe, 61
Dye testing
  equipment, 233
  illegal connections, 233
  inflow, 233
  operation, 233
  purpose, 233, 267
Dyes, velocity estimation, 59
Dynamite, 71

E

EPA Pesticides Regulation Division, 339
Earth movement, 16
Easements, restoration, 91
Economics, TV inspection, 242
Electrical, safety, 153-160
Electrochemical sensors, 143
Electronics, monitors, 144
Emergency
  conditions, 63
  service, 17, 18, 369
  stoppages
    see Stoppages
Enclosure, manhole, 124
Equipment
  air testing, 94
  balling, 268, 273, 282
  bucket machines, 268, 306, 307
  compaction, 88-91
  excavation, 71
  flushing, 269, 294
  hand rods, 268, 329
  hazardous gas detection equipment, 137
  high velocity cleaners, 268, 288
  inspection, 114, 115
  lamping, 234
  manhole inspection, 185
  repair, 395, 401
  rodders, power, 268, 317, 318, 320, 321, 325, 328
  rodding, 268, 317, 318, 320, 321, 325, 328
  safety
    see safety equipment
  scooters, 269, 301
  service lines, 395
  smoke testing, 225
  television inspection, 192, 223, 240, 242-254
  underground work, 395
Examinations, 9
Excavation, 71-82, 398, 402
Excavation
  construction, 71
  equipment, 71
  inspection, trenches, 93
  spanning, 402
Exfiltration, 16, 181, 183, 229, 233
Explosimeter, 137
Explosive atmospheres, 132, 137, 150
Explosive monitor, 142

F

FRP, 62
Failures, lift stations, 264
Fair lead pulley, 192
Fiberglass
  manholes, 63
  reinforced pipe, 62
Field investigation, design, 63
Field notes, survey, 57, 58
Field surveys, 52
Final inspection, 103
Fire extinguishers, 161
Fire fighting, 161
Fire hydrant, 292
First aid, 342
First-aid kit, 146
Fixed-beam laser, 82, 83
Flagmen, 117, 121
Flags, traffic, 117, 119
Flammable atmospheres, 132
Flexible pipes and joints, 16, 61, 62
Floats, velocity estimation, 39
Flotation of sewer, 17
Flow
  design, 57
  fluctuations, 41, 42
  gravity, 16
  maximum, 37, 38
  measurement, 39
  minimum, 37, 38
  quantity, 37, 38
  regulators, 52, 54, 56
  variation, 41, 42
  velocity, 59, 273
Flow in sewer trench, 17
Flows, 38
Fluid, shoring, 378
Flusher branches, 48
Flushing
  advantages, 269
  application, 265, 267, 269, 294
  crews, 294
  equipment, 269, 294
  limitations, 269
  manpower, 294
  operation, 295, 296
  precautions, 273, 296
  records, 270, 297
  safety, 296
  set up, 296
  use, 265, 267, 269, 294
Footage meter, 204
Forms
  manhole entry, 149
  manhole inspection, 186, 189
  TV inspection, 206, 214, 216

Foundations, pipe, 86
Frame, manhole, raising, 410, 414
Frequency, balling, 273
Funds, for collection systems, 6

G

GFI, 158, 159
Garber, William, 345
Gas detection equipment, 137
Gas hazards, 132
Gas test kit, 137
Gasket, pipe, 62
Glossary, 431
Gloves, 146
Go, no go test, 102, 103
Goggles, safety, 146
Grade
  control, sewers, 78-82
  pole, 80-82
  ring, manhole, 410
  sewer, 78-82
  string line, 80, 81
Gravity collection system, 42, 43, 44
Gravity flow, 16
Gravity sewers, 44
Grease, 264, 266, 269, 326, 342, 343
Grease traps, 342, 343
Grinder pumps, 44
Grit, 267, 269, 326
Ground fault interrupter (GFI), 158, 159
Groundwater
  infiltration, 17, 181
  pollution, 16, 181, 183
Grout sealing, 405
Guniting sewers, 410

H

Hand rods
  also see Rodders, power
  advantages, 268
  application, 265, 266, 269, 329
  emergency stoppages, 329
  equipment, 268, 329
  limitations, 268
  manpower, 329
  operation, 329, 330
  precautions, 329
  records, 270, 332
  safety, 329
  service request crews, 329
  set up, 329
  use, 264, 266, 269, 329
Handhole trap, 44
Handling sewer pipe, 86
Hard hat, 146
Harness, safety, 137-139
Hat, hard, 146
Hazardous wastes, 135
Hazard communication, 161-169
Hazards
  also see Safety hazards
  atmospheric, 132
  explosive atmospheres, 132
  flammable atmospheres, 132
  oxygen deficient atmospheres, 132
  toxic atmospheres, 132
Health
  community, 7, 17
  hazard, 133, 181
  operator, 146, 148
  public, 7, 17
Hearing protection, 160
Hertz, 200
High velocity cleaning machines
  advantages, 268
  application, 265-267, 269, 277, 278, 290
  blowing toilets, 223
  cleanout, 203
  cold weather, 293
  crews, 288
  equipment, 268, 288, 292
  inverted siphons, 293
  limitations, 268
  maintenance, 268
  manpower, 288
  operation, 289-291
  precautions, 273, 293
  records, 270, 294
  safety, 292, 293
  set up, 292
  stoppages, 292
  TV camera, use, 294
  use, 265-267, 269, 287, 288, 290
Hoffer, Eric, 16
Holding tanks, 44
House trap, 47, 48
Hydraulic methods, 265, 273
Hydraulic overload, 182
Hydraulic sewer cleaning
  bags, 265
  balls, 265-267
  causes and control, 208, 265, 267, 343
  chemical control, 346, 347
  chlorine, 348
  control, 345, 347
  corrosion, 345
  design, 345
  dissolved sulfide, 347
  equipment, 273
  explosive, 345
  flammable, 345
  flushing, 265-267, 287
  hydrogen peroxide, 348
  industrial waste dischargers, 346
  jets, 265-267
  kites, 265-267
  lime, 349
  methods, 265, 269
  odors, 345
  oxidation reduction potential, 347
  pH, 345
  packed absorption towers, 346
  parachutes, 265
  poisonous, 345
  precautions, 273
  production, 345
  pure oxygen, 349
  rotten egg odors, 345
  scooters, 265-267, 297
  sewer balls, 265
  sewer-use ordinances, 346
  tires, 265
  toxic, 345
Hydraulic shores, 378, 379
Hydraulic shoring, 73, 76
Hydrogen peroxide, 348
Hydro-brake, 52, 56

Hydrogen sulfide
  activated carbon towers, 346
  air, 349
  monitor, 142
Hydrochloric solution, 222, 275
Hydrophilic, 406

I

I & I (inflow/infiltration), 16, 17
Illegal taps, 370-372
Immunizations, 133, 148
Imported backfill, 99
Improper taps, 370
Industrial waste discharges, 182, 343, 346
Infections, 133
Infiltration, 16, 17, 36, 37, 181, 182, 233, 240
Inflow, 16, 17, 36, 182, 229, 233, 240
Injury, physical, 133
Inoculation, 17
Insects, 135, 344
Inside drop, manhole, 416, 417
Inspection
  appurtenances, 93
  appurtenance construction, 94
  backfill, 93, 94
  bedding, 93
  collection systems, 18, 19, 36, 92, 181
  compaction, 94
  concrete, 93
  construction, 18, 92-94
  excavation, 93
  final, 103
  inspector duties, 92
  materials, 92
  pipe bedding, 93
  pipe laying, 93
  qualifications, 92
  safety, 114
  sewer pipe, 92
  sewers, 65
  system, 267
  TV, 191, 267
  TV codes, 242-244
  TV equipment, 252-254
  visual, 267
Inspector
  construction, 92
  duties, 92
  manual, 92
  need, 92
  qualifications, 92
  reports, 204
Installation tools, shoring, 380
Intercepting sewers, 42, 43
Interconnector sewers, 52
Intrusion of roots, 16, 62, 181
Inverted siphon, 52, 55, 293, 297

J

Jackhammer, 71
Jacks, shoring, 375, 381
Jet sewer cleaners, 265-267
Jobs for operators, 7, 8
Joining of pipe, 86, 87
Joints
  pipe, 62, 86
  problems, 181
  sewers, 16
  type, 62
Jump joint, 217, 218
Jumpers, air, 52, 55
Junction structures, 52, 54

K

Kit, first-aid, 146
Kites, 265-268, 303

L

LEL, 131, 143, 144
Labels, hazard, 163-169
Lamp holes, 48
Lamping, pipeline
  comments, 234
  equipment, 234
  manpower, 234
  operation, 234
  purpose, 233, 267
Laser fixed-beam, 82, 83
Lateral sewer cleanout, 48
Lateral sewers, 42, 43
Lawrence, C.H., 347
Laying pipe, 86, 93
Layout, design, 52
Leakage, 17, 94, 101, 181, 414
Leptospirosis, 133
Letters to public, 227
Level surveys, 55
Level wind system, 334
Lid lifter, manhole, 152
Lifeline safety, 137-139
Lift stations
  failures, 18, 264
  sketch, 48
  use, 44
Lime, 349
Loading, pipe, 60, 61
Location of
  building sewers, 47, 48, 104, 107
  sewers, 60
  utilities, 71, 93, 104
Lockout, procedure, 158, 160
Logarithmic scale, 95
Logging data
  manhole inspection, 186-189
  TV inspection, 205
Low pressure collection system, 44, 45
Lower explosive limit (LEL), 131, 143, 144

M

MSDS, 162-169
Main sewers, 42, 43 369, 399, 401
Main trap, 47, 48
Maintenance
  bucket machines, 333
  cleaning sewers, 265
  cold weather, 293, 336
  collection systems, 9, 16, 17, 18, 63
  design, 63
  engines, 336
  flows, impact on, 37-39
  high velocity cleaner, 335
  objectives, 264
  power rodders, 328, 334, 335
  preventive, 16, 17, 192, 333, 369
  rodders, 328
Mandrel test, 102, 103
Manhole hazards
  access, 146

Manhole hazards (continued)
  atmospheric hazards, 132
  bugs, 135
  classification, 124
  confined spaces, 124
  dangerous air contamination, 131
  depletion of oxygen, 131
  description, 124
  diseases, 133
  drowning, 135
  explosive atmospheres, 131, 132
  flammable atmospheres, 113, 132
  hazardous wastes, 135
  hydrogen sulfide, 132
  infections, 133
  insects, 135
  insufficient ventilation, 132, 144
  leptospirosis, 133
  methane gas, 132
  natural gas, 132
  olfactory fatigue, 151
  oxygen deficiency, 131, 132
  physical conditions, 146
  physical injury, 133
  rodents, 135
  sharp objects, 133
  slippery surfaces, 133
  spiders, 135
  toxic atmospheres, 131, 132
  toxicants (liquids and solids), 135
  traffic, 116
  ventilation, insufficient, 144
Manhole inspection
  equipment, 185
  forms, 186
  frequency, 186
  manpower, 185
  procedures, 185
  safety, 185
Manhole lid lifter, 277
Manhole repairs
  barrels, 416
  bottoms, 414, 415
  channel corrections, 416
  cover, raising, 410
  inside drop, 416, 417
  leaks, 414
  outside drop, 416, 417
  raising frame and cover, 410, 414
  site preparation, 412
  spacers, 410
  speed-crete, 416
Manhole safety
  alarm unit, 137, 144
  atmospheric alarm unit, 137, 144
  atmospheric hazards, 132
  bugs, 135
  confined space entry form, 149
  confined spaces, 124
  diseases, 133
  drowning, 135
  entering a manhole, 146
  equipment, 135-148
  infections, 133
  insects, 135
  laundry, 146, 153
  manhole entry, 146-153
  physical injury, 133
  portable atmospheric alarm unit, 137, 144
  precautions, 146
  procedures, 135-153
  rodents, 135
  spiders, 135
  toxicants, 135
  traffic, 116
  ventilation, 144
Manholes
  access, 146
  construction, 53, 87, 88, 94
  entry, 135-153
  entry form, 149
  fiberglass, 63, 88
  grade ring, 405
  hazards, 124
  infiltration, 183
  insects, 135, 344
  inside drop, 416
  inspection, 185
  lid lifter, 152, 277
  missing, detection, 405, 410
  noisy, 18
  plan review, 63
  precast, 53
  purpose, 49, 63
  repairs, 183, 369, 404, 410-418
  responsibility, 153
  safety equipment, 135-146
  safety hazards, 63, 124
  sketch, 53
  specification review, 63
  use, 48
Manning equation, 59
Manpower for
  also see Staffing
  air testing, 97
  balling, 273
  bucket machines, 308
  flushing, 294
  hand rods, 329
  high velocity cleaners, 288
  lamping, 234
  manhole inspection, 185
  rodders, power, 320
  scooters, 301
  smoke testing, 228
  TV inspection, 199
  underground repair, 401
Masking agents, 343, 344
Material Safety Data Sheets (MSDS), 162-169
Materials for
  backfill, 88
  manholes, 63
  pipe, 61
  repairs, 395, 401
  sewers, 61
  testing, 92
Materials inspection, 92, 93
Mathematics, 471
Maximum flows, 37, 38
Measurement
  compaction, 91
  flow, 39
Mechanical compaction, 90, 91
Mechanical sewer cleaning
  bucket machines, 265, 267, 306
  hand rods, 265, 266, 269
  methods, 265, 306
  power rodders, 265, 266, 269, 317
  rodding, 265, 266, 269, 317

Meetings, 374
Metal-wood shoring, 73
Minimum flows, 37, 38
Monitors, atmospheric, 142
Monitors, electronic, 144
Monthly reports, 104

N

National Fire Prevention Association, 161
Native backfill, 88
Native material, 85
Natural gas, 93
Negligence, 17
New construction, 369, 418
Noise, safety, 160
Nonreinforced concrete pipe, 62
Notifying authorities, 270, 294

O

ORP, 347
OSHA, 8, 72-77, 375, 378
Objectives, sewer maintenance, 264
Occupational Safety and Health Act, 8, 72-77, 375, 378
Odors, 17, 18, 36, 63, 264, 267, 269, 343
Offset, 217
Olfactory fatigue, 151
Operation
  dye testing, 233
  lamping, 234
  smoke testing, 228
  TV inspection, 199
Operation and maintenance,
  collection systems, 9, 16, 17, 18, 181, 264
Operator, collection system
  health, 146, 148
  jobs, 7
  pay, 8
  recognition, 7
  training, 4, 9
  training, hazardous materials, 164
Orifice, 336
Outside drop manhole, 416, 417
Oxidation reduction potential, 347
Oxygen deficiency, 131, 132, 137
Oxygen deficiency tester, 137
Oxygen, monitor, 142
Oxygen, sulfide control, 349
Ozone, 350

P

PL 92-500, 17
PVCP, 62
Packed absorption towers, 346
Packer, sealing, 407-410
Parachutes, 265
Parking vehicles, 117
Pavement, cutting, 401
Pay for operators, 8
Peak flows, 37, 38
Peaking factor, 37
Pedestrian safety, 377
Permits, traffic routing, 401
Pesticides Regulation Division, EPA, 339
Physical injury, 133
Pintle hook, 401
Pig, 44
Pipe
  backfill, 82-85, 88, 89
  bedding, 82-85
  bell and spigot, 61, 62, 86
  braces, shoring, 375
  deflection, 62, 86
  flexible, 61, 62
  foundations, 86
  gasket, 62, 86
  grade pole, 80, 81
  handling, 86
  inspection, 83, 92, 93
  joining, 86
  joints, 16, 62
  laying, 85, 86, 93
  loading, 60, 61
  materials, 61, 62
  placement, 86, 89
  protection, 86, 89
  rigid, 61, 62
  safety rules, 86
  spigot, 61, 62, 86
  storage, 86
Placement of backfill, 89, 90
Placement of pipe, 86
Placing spoil, 376
Plan and profile, sewer, 63, 64
Plan review, 63
Planning repairs, 374
Plans, "as-built", 104
Plugs, air, 97
Plumber-made stoppages, 264
Polaroid cameras, 208
Policy
  grease traps, 342
  service, 17
  stoppages, 6
Pollution, groundwater, 16
Poly pigs, 232, 234
Polymer, 406
Polyvinylchloride pipe, 62
Pomeroy, Richard, 346
Porcupine, sewer cleaning, 307
Porcupine tool, 314, 322
Portable atmospheric alarm unit, 137, 142
Portable traffic arrows, 117, 123
Portland cement, concrete, 85, 93
Power bucket machines
  see Bucket machines
Power rodders
  see Rodders, power
Power winch, 275, 313
Precautions
  televising sewers, 215
  TV inspection, 210
Preconstruction meeting, 374
Preliminary investigation, sewer repair, 394
Pressure gages, 94
Pressure mains, 44
Preventive maintenance, 16, 17, 192, 333, 369
Problems, causes
  collection systems, 181
  construction, 370
  design deficiencies, 181, 370
  disasters, 182
  exfiltration, 183
  grease, 182
  identification, 264
  industrial waste discharges, 182
  infiltration, 182
  inflow, 182

Problems, causes, (continued)
  inspection, 182
  installation, 182
  roots, 182
  service connections, 182
  sewer-use ordinances, 182
  sulfide, 182
  surcharging, 182
  tap-ins, 182
  temperature, 182
Procedures
  air testing, 94
  confined space entry, 135-153
  construction and inspection, 93
  laying sewer pipe, 86, 87
  lockout, 158, 160
  manhole entry, 135-153
  manhole inspection, 185
  sewer pipe laying, 86, 87
  TV inspection, 199
  underground repair, 398
  water testing, 101
Profile, sewer, 58, 63, 64
Protecting pipe, 86
Protection, hearing, 160
Protection of pipe, backfilling, 89
Protective clothing, 146
Protective shields, 76
Protruding taps, 219
Public contacts, 227, 374, 394
Public health, 7, 17, 344
Public Law 92-500, 17
Public recognition, 7
Public relations
  contacting public, 227, 374, 394
  importance, 374, 394
  letters to public, 227
  public contacts, 227, 374, 394
Public Works Inspector's Manual, 92, 108
Pump stations
  see Lift stations
Pure oxygen, 349
Purpose, collection systems, 37

Q

Quantity of wastewater, 36, 37

R

RCP, 62
RPMP, 62
Raising manhole frame and cover, 410-414
Rats, 344
Recognition, operator, 7
Recordkeeping
  as-built plans, 104
  balling, 270, 287
  bucket machines, 270, 317
  collection systems, 17
  construction, 104
  daily report, 104, 270, 271
  flushing, 270, 297
  hand rods, 270, 332
  high velocity cleaners, 270, 332
  maintenance reports, 270, 271
  monthly reports, 104
  power rodders, 270, 328
  rodders, 270, 328
  scooters, 270, 303
  sewer locations, 71, 104
  smoke testing, 229
  TV inspection logs, 205, 221
Records, construction, 104-108
Recovery of broken rods, 326, 327
Regulators, flow, 52, 54, 56
Rehabilitation, 240
Reinforced concrete pipe, 62
Reinforced plastic mortar pipe, 62
Removal of shoring, 72-77, 375-391
Repair, collection systems, 63, 394
  also see Underground work and Manhole repairs
Repairs
  manholes, 410-418
  tools, 395, 401
Reports
  construction, 104-106
  TV inspection, 214, 216
Repose, angle of, 376
Responsibility, 92, 153, 333, 376
Responsibility, confined space, 153
Responsibility, manholes, 153
Restoration, surface, 91, 92, 94, 403
Retaining walls, 72
Right-to-know laws, 161-169
Rigid pipe, 61, 62
Risers, 63, 87, 410-414
Rodders, power
  also see Hand rods
  accessories, 318
  advantages, 268
  application, 265, 266, 269, 317
  broken rods, 326, 327
  classification, 319
  clean up, 326
  coil rodders, 319
  continuous rodders, 319, 328, 335
  crews, 320
  equipment, 268, 317, 319, 320, 321, 325, 328
  emergency use, 317
  grease, 326
  grit, 326
  hydraulic unit, 335
  limitations, 269
  maintenance, 328, 334, 335
  manpower, 320
  operation, 317, 325
  porcupine, 322
  precautions, 327
  records, 270, 328
  recovery of broken rods, 326, 327
  roots, 326
  safety, 325-327
  sectional rodders, 319, 329
  set up, 225
  tools, 321-325
  use, 265, 266, 269, 317
Rodents, 135, 344
Roots
  causes, 370
  control, 340-342
  damage, 370
  herbicide, 340
  intrusion, 16, 62, 181
  rating system, 205, 207
  removal, 264, 266, 326
  safety, 342
  solutions to problem, 269
  stoppages, 18, 264, 266, 370

- Rotameter, 350
- Route surveys, 52
- Routing traffic, 116-130
- Running soil, 376

S

- Safe procedures
  - after leaving manhole, 153
  - air testing, 96-100
  - balling, 281, 287
  - briefing, 148
  - bucket machines, 314, 316
  - chlorine handling, 348
  - cleaning sewers, 116-124
  - confined spaces, 124
  - flushing, 296
  - hand rods, 329
  - high velocity cleaners, 291, 293
  - laundry, 153
  - laying pipe, 86
  - manhole entry, 146
  - manhole inspection, 185
  - power rodders, 325-327
  - scooters, 301-303
  - sewer pipe laying, 86, 87
  - shoring, 375, 377, 391
  - traffic routing, 116-124
  - underground repair, 369, 403
  - water testing, 101, 102
- Safety
  - atmospheric alarm unit, 137, 142
  - confined spaces, 124
  - construction, 71
  - defensive driving, 115
  - detection of hazardous gases, 137-144
  - diseases, 133
  - driving, 115
  - electrical, 153-160
  - equipment
    - also see Safety equipment
    - approved, 135-146
    - inspection, 114
    - manhole entry, 135-146
  - excavations, 71, 72, 377-391
  - fire fighting, 161
  - first aid, 146
  - gases, 132
  - gloves, 146
  - hard hat, 146
  - harness, 137-139
  - hazard communication, 161
  - health of operators, 146-148
  - lifeline, 137-139
  - manhole entry, 124-153
  - manhole hazards, 124
  - noise, 160
  - protective clothing, 146
  - routing traffic, 116
  - shoring, 71-77, 377-391
  - trenching, 71-77, 377-391
  - tripod and winch, 137, 140, 141, 146
- Safety equipment
  - alarm unit, 137-143
  - atmospheric alarm unit, 137-143
  - barricades, 117, 118, 122, 146
  - blowers, 144, 145
  - clothing, 146, 322
  - cones, 117, 118, 122, 146
  - ear protection, 160
  - enclosure, handhole, 146
  - explosimeter, 137-143
  - fire extinguishers, 161
  - first-aid kit, 146
  - flags, 117, 119, 122, 146
  - gas test kit, 137-143
  - goggles, 146
  - hard hat, 146
  - harness, 137
  - ladders, 146
  - life jacket, 135
  - manhole entry, 135-153
  - noise protection, 160
  - personal, 395
  - protective clothing, 146, 322
  - repairs, 395
  - ropes and buckets, 146
  - self-contained breathing apparatus, 135, 136
  - shoring, 30, 71-77, 377-391
  - signs, 117-123
  - underground repairs, 401
  - ventilation blower, 144, 145
  - winch, 137
- Safety harness, 137
- Safety hazards
  - access to manholes, 124, 125
  - air testing, 94-100
  - atmospheric hazards, 132
  - balling, 281, 287
  - below grade work, 8
  - blasting, 71
  - bucket machines, 314, 316
  - bugs, 135
  - cable operated equipment, 316
  - cave-ins, 71-77, 369, 375-391
  - chemicals, 342
  - cleaning sewers, 117
  - confined spaces, 8, 124
  - dangerous air contamination, 124
  - diseases, 133
  - driving, 115, 292
  - drowning, 135
  - dynamite, 71
  - electrical wires, 133, 153-159
  - excavation, 71
  - explosive atmospheres, 124, 137
  - flooded basements, 6
  - flushing, 296
  - gas leak, 6
  - gasoline vapor, 132
  - hand rods, 331
  - handling pipe, 86
  - hazardous wastes, 135
  - health, 7, 181
  - high velocity cleaner, 292, 293
  - hydrogen peroxide, 132
  - hydrogen sulfide, 132
  - infections, 133
  - insects, 135
  - lamping, 234
  - manholes, 124-135
  - methane gas, 132
  - natural gas leak, 6, 132
  - noise, 160
  - olfactory fatigue, 151
  - overhead electrical wires, 63
  - oxygen deficiency, 132, 137-143
  - oxygen, pure, 349
  - pipe handling, 86

Safety hazards (continued)
  physical injury, 133
  poisonous gases, 132
  power rodders, 326, 327
  public health, 7
  pure oxygen, 349
  rewinding cables, 222
  rodders, power, 326, 327
  rodents, 135
  root control, chemicals, 342
  scooters, 301-303
  sharp objects, 133
  shoring, 71, 375
  slippery surfaces, 133
  smoke bombs, 227
  sodium hydroxide, 350
  TV inspection, 200
  toxic atmospheres, 132, 137-143
  toxic gases, 132, 137-143
  toxicants (liquids and solids), 135
  traffic, 116-124
  trenching, 71
  underground utilities, 93
  underground work, 8
  vehicle inspection, 114
Safety, manhole entry
  see Manhole safety
Sand, 167, 169
Sand trap, 284, 291, 301
Sanitary wastewater collection system, 36
Sanitation, 17
Schedule, maintenance, 37
Scooters
  advantages, 269
  application, 265, 266, 269, 297
  equipment, 269, 298, 301
  inverted siphons, 297
  limitations, 269
  manpower, 301
  operation, 299, 302
  precautions, 273, 303
  records, 270, 303
  safety, 301-303
  set up, 301
  use, 265-267, 297
Scouring velocities, 57, 59
Scraper, 269
Screw jack, 74
Screw-type jack, 375, 381
Sealing
  chemicals, 206
  equipment, 405
  grout, 405
Search for leaks, 94, 101
Sectional rodders, 319, 328
Seepage, 17
Selection of chemicals, 338
Self-contained breathing apparatus, 135-137
Sensors, atmospheric alarm, 143
Septic, 52, 132, 346
Service lines, 369
Service request crews, 329
Settling of sewers, 16
Sewer
  balls
    see Balling
  pipe, inspection and testing, 92
  pipe joints, 62
  size, 59
  slope, 57
  velocity, 57, 59
Sewer pipe, inspection and testing, 92
Sewer trenches, 17
Sewer-use ordinances, 182, 346
Sewers
  alignment, 60
  appurtenances, 44, 93
  branch, 42
  building, 42, 104
  cleaning methods, 265
  cleaning porcupine, 307
  cleaning swab, 307, 313
  construction, 65, 70
  construction inspection, 92-94
  cut sheet, 80
  depth, 60
  grade, 57, 59, 60
  grease, 264, 266
  guniting, 410
  inspection, 65, 92-94
  intercepting, 42
  lateral, 42
  leaks, 17, 94, 101, 181
  loading, 60, 61
  line, 60
  location, 60, 93
  main, 42
  manhole entry, 135-153
  materials, 61, 62
  objectives, maintenance, 264
  plan and profile, 58, 63, 64
  rehabilitation, see Chapter 10
  roots, 264, 266
  safety, 109-169
  shoring, 71-77, 375-391
  slope, 57, 59, 60
  stoppages, 264, 266, 317
  testing, 65, 94-102
  traffic routing, 116-124
  types, 42, 43, 44
  use, problems caused, 181
Sharp objects, 133
Sheet shoring, 75, 76
Sheeting, 379, 385
Shield shoring, 387-391
Shoring
  access to excavation, 377
  air shores, 382, 384
  angle of repose, 376
  braces, 375, 376
  cave-ins, 375
  construction, 71-78
  crib, 387
  cross braces, 376
  cylinder shoring, 386
  fluid, shoring, 378
  hydraulic shores, 378, 379
  installation tools, 380
  jacks, 375, 381
  location of trench, 377
  need for, 71, 72, 375
  OSHA, 72-77, 375, 378
  pedestrian safety, 377
  pipe braces, 375
  placing soil, 376
  removal, 89
  repairs, 375-391
  repose, angle of, 376

- Shoring (continued)
  - requirements, 375, 377
  - responsibility, 376
  - running soil, 376
  - safety, 377, 391
  - screw-type jacks, 375, 381
  - sheeting, 383, 385
  - shield shoring, 387-391
  - sloping excavation walls, 377
  - soil stability, 375-377
  - solid sheeting, 383, 385
  - spoil, 376
  - stringers, 376, 383, 386
  - Tacoma, Washington, 387
  - tools, 380
  - trench location, 377
  - trenches, 72-78
  - types of shoring, 378
  - uprights, 376
  - uses, 375
  - walers, 383
  - wood braces, 375
- Signs, traffic, 116-124
- Siphons, inverted, 52, 55
- Size, sewer, 59
- Slanted risers, 48, 51
- Slippery surfaces, 133
- Slope of sewer, 57
- Sloping excavation walls, 377
- Smoke testing
  - air flow, 228
  - blower, 225
  - bombs, 225
  - crews, 228
  - equipment, 225
  - exfiltration, 229
  - illegal connections, 225
  - inflow/infiltration, 182, 225, 229
  - manpower, 228
  - operation, 228
  - pipe plugs, 225
  - preparations, 227
  - public announcement, 227
  - purpose, 225, 267
  - recordkeeping, 229
  - safety, 227
  - smoke bombs, 225
  - uses, 182
- Sodium hydroxide, 349
- Sodium hypochlorite, 348
- Soil stability, 375-377
- Solid sheeting, 383-385
- Sources of problems, 370
- Spacer, manhole, 410-414
- Spanning excavations, 404
- Specific gravity, 132
- Specification review, 63-65
- Speed-crete, for repairs, 416
- Spigot, pipe, 62, 86
- Spoil, 376
- Springline, 34
- Staffing
  - also see Manpower for
  - balling crews, 273
  - bucket machine crews, 308
  - flushing crews, 223, 294
  - high velocity cleaners, 288
  - power rodders, 320
  - smoke testing, 228
- Stoppage
  - broken pipe, 264
  - causes, 17, 18, 264, 266, 293
  - correction, 264, 266, 370
  - debris, 264
  - emergency, 269, 293, 317, 329
  - grease, 264, 266
  - hydraulic, 265
  - joint failure, 264
  - plumber-made, 264
  - roots, 264
  - vandal caused, 264
- Stopping distance, safe, 116
- Storage of pipe, 86
- Storm water collection system, 36
- String line, 80, 81
- Stringers, 376, 383, 386
- Structures
  - junction, 52, 54
  - settling, 16, 85
- Subsidence, 85
- Sulfide control, 63
- Sulfide, dissolved, 347
- Surcharge, 182, 404, 410
- Surface drainage, 182
- Surface restoration, 91, 92
- Survey, field, 52
- Surveyor, 55, 78-80
- Surveys
  - field, 52
  - level, 55
  - route, 52
- Swab, sewer cleaning, 307, 313

T

- TV inspection
  - see Television inspection
- Tacoma, Washington, 387
- Taps, 48, 50, 370-372
- Tees, 48, 93
- Televising sewers, precautions, 215
- Television inspection
  - acceptance of contractor's work, 192
  - camera underwater, 217
  - cleaning camera, 222
  - codes, 242-244
  - collection systems, 19
  - commands, 203
  - crews, 100
  - drop joint, 217, 218
  - economics, 242
  - equipment, 192, 222, 223, 241, 242-254
  - errors, 220
  - final check of tests, 220
  - final inspection, 103, 240
  - fogging of viewport, 219
  - footage meter, 183, 204, 220, 241
  - form, 206
  - high velocity cleaner, 294
  - illegal taps, 240
  - infiltration/inflow, 240
  - jump joint, 217, 218
  - location of problems, 192
  - logging data, 205, 221
  - maintenance, 240, 267
  - manpower, 199
  - notification of operators, 199
  - offset, 217
  - operation of TV, 192

Television inspection (continued)
  photographic TV picture, 223
  polaroid cameras, 208, 223
  precautions, 217
  problem areas, 192
  procedure, 199
  protruding taps, 219
  purchase of equipment, 222, 241
  purpose, 191, 192, 240
  recording data, 205, 206, 209, 221
  rehabilitation, 240
  removal of equipment, 220
  rent equipment, 240, 241
  rewinding cables, 222
  root intrusion, 219
  root rating system, 205, 207
  safety, 200, 222
  set up of equipment, 199
  sewers, 19, 267
  shut down, 220
  size of sewers, 192
  taps, illegal, 240
  testing, 94-102
  under water, 218
  use, 192, 240
  video tape, 208, 223
  viewport fouled, 217, 219
Test section of sewer, 339
Testing
  air, 94-101, 181
  appurtenances, 92
  backfill, 93
  collection systems, 94-102, 181
  concrete, 93
  construction, 92
  dye, 233, 267
  go-no go, 102
  lamping, 233, 267
  Mandrel, 102
  materials, 92
  pipe bedding, 93
  pipes, 94-102
  pressure, air, 94-100
  purpose, 94, 101, 102
  sewer pipe, 92
  sewers, 65, 94-102
  smoke, 182, 225, 267
  test pressures, 94-100
  volume of air, 95
  water (sewer leaks), 101-102, 267
Tetanus, 133, 146
Three edge bearing load, 84
Tires, sewer cleaning, 265, 285, 303
Tools, repair, 395, 401
Toxic atmospheres, 132, 137
Toxicants (liquids and solids), 135
Traffic
  arrows, 117, 123
  problems caused by, 181
  routing, 116-130
  vibrations, 181
Traffic safety
  arrows, 117, 123
  flagmen, 117, 121
  notifying authorities, 117
  parking vehicles, 117
  routing traffic, 116-124
  signs, 117-120
  vehicles, parking, 117
  warning devices, 117-124
Training, collection system operator, 4, 9
Training operators, hazardous materials, 164
Trap vent, 47
Traverse route surveys, 52
Treatment plant overload, 16
Treatment plants, 36, 181, 182, 270, 294, 341, 344, 347, 350
Trenches
  backfill, 82-86, 88-91
  backfilling and compaction, 94
  bedding, 82-86, 88-91
  cave-ins, 369, 375
  depth and width, 71
  excavation, 71
  inspection, 93
  location, 377
  sewer, 17
  shoring, 71-77, 375-391
Trench shoring, 72-78
Trenching machines, 71
Tripod, 137
Tripod, safety, 137, 140, 141
Troubleshooting collection systems, 19
Trunk sewers, 42, 43
Tunneling machines, 71
Turbulence, flow, 36
TV inspection
  see Television inspection
Types of shores, 378
Typhoid, 133

U

USA, 72
Underground Service Alert, 72
Underground work
  as-builts, 402
  assignment of repair jobs, 370, 395, 401
  backfilling, 399, 403
  band couplings, 403
  bedding, 399, 403
  causes of problems, 370
  cleanouts, 399
  compaction, 403
  construction, new, 369, 418
  couplings, band, 399
  cutters, pipe, 398, 399
  cutting pavement, 402
  damages, 370
  demand for repair, 369
  equipment, 395, 401
  excavation, 398, 402
  forms, 370
  improper taps, 370
  location of sewer, 399
  main lines, 369, 401
  manholes, 369, 404
  manpower, 401
  materials, 395, 401
  meetings, 374
  new construction, 369, 418
  pavement, cutting, 402
  permits, 401
  planning repairs, 374
  preconstruction meeting, 374
  preliminary investigation, 394, 401
  problems, 370
  procedures, 398
  public relations, 374, 394

Underground work (continued)
  repair, 369, 370, 374, 394, 401-403
    also see Manhole repairs
  restoration, 403, 418
  roots, 370
  safety, 369, 403
  service lines, 369, 394, 399
  shoring, 375, 402
  sources of problems, 370
  stoppages, 370
  taps, 370
  tools, 395, 401
  types, 369
  utility companies, 374, 394
  water table, high, 402
  work request form, 370
Unions, labor, 8
Uprights, shoring, 376
Utilities, location, 79, 93, 104
Utility companies, 374, 394

V

VCP, 62
Vaccination, 17, 146
Vacuum collection system, 44, 46
Vacuum device, cleaning, 291
Vacuum interface unit, 44, 46
Vacuum mains, 44, 46
Vacuum pumps, 44
Vandalism, 17, 370, 414
Vector control, 344
Vehicle inspection, 114, 115
Vehicles, parking, 117
Velocity
  dye, 233
  flow, 39, 59, 273
  measurement, 39, 233
  scouring, 57, 59
Velocity, in sewer, 57, 59
Vent traps, 47, 48
Ventilation
  blowers, 144-146, 148
  manholes, 144, 145, 148
  sewers, 63, 148
Vertical risers, 63, 98
Vibrations, traffic, 16
Video tape, 208, 223
Vitrified clay pipe, 62

W

Walers, 383
Waring, George E., 17
Warning devices, 117-123
Wastewater collection systems
  see Collection systems
Wastewater quality, 36
Wastewater treatment plants, 36, 181, 182, 270, 274, 294, 341, 344, 347, 350
Water compaction, 89-91
Water department notification, 294
Water Pollution Control Federation, 9
Water testing, 101, 102
Water testing (sewer leaks), 101, 102, 267
Weir type flow regulator, 52, 54, 56
Weirs, use, 52, 54, 56
Welding huts, 78
Well point, 71
Wells, water, 183
Wetted perimeter, 60
Winch, 137, 275, 313
Winch, power, 275, 313
Winch, safety, 137, 140, 141
Wood braces, shoring, 375
Words, collection system, 431
Work assignment, 270
Work request form, 270, 370
Worker right-to-know laws, 161-169
Wyes, 48, 93